AN ANALYSIS OF TRAFFIC ACCIDENTS ON A HIGH-VOLUME HIGHWAY

JULY 1965
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by

A. O. PETERSON

Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Progress Report

AN ANALYSIS OF ACCIDENTS ON A HIGH-VOLUME HIGHWAY

To: G. A. Leonards, Director
Joint Highway Research Project

July 9, 1965

From: H. L. Michael, Associate Director
Joint Highway Research Project

File: 8-7-2
Project: C-36-66B

The Progress Report attached "An Analysis of Traffic Accidents on a High-Volume Highway" is submitted on the HPR-HPS Project, Traffic Engineering Demonstration on the US 52 By-Pass, Lafayette, Indiana. It has been authored by Arvid Peterson, Graduate Assistant on our staff with the guidance of Professor H. L. Michael. Mr. Peterson also used the report as his thesis for the MSCE degree.

This report and a companion report on travel delays on the same facility will be the basis of recommendations for traffic engineering improvements on the by-pass. This recommendation report will be prepared during the next few months.

The report will also be submitted to the State Highway Commission and to the Bureau of Public Roads for their review and comment. It is submitted to the Board as information and for the record.

Respectfully submitted,

Harold L. Michael

Harold L. Michael, Secretary

HLM:bc

Attachment

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Progress Report

AN ANALYSIS OF ACCIDENTS ON A HIGH-VOLUME HIGHWAY

by

Arvid O. Peterson
Graduate Assistant

Joint Highway Research Project

File No: 8-7-2

Project No: C-36-66B

Prepared as Part of an Investigation

Conducted by

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Engineering Experiment Station
Purdue University

in cooperation with

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or the
Bureau of Public Roads

Purdue University
Lafayette, Indiana
July 9, 1965

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The confidence, patience and assistance of the author's wife and family has been greatly appreciated.

TABLE OF CONTENTS

LIST OF TABLES v

LIST OF FIGURES vii

ABSTRACT xiii

INTRODUCTION 1

PURPOSE 4

THE STUDY LOCATION 4

PREVIOUS INVESTIGATIONS 5

Multiple Linear Regression 5
Quality Control 8
Traffic Engineering Improvements 9

PROCEDURE 12

Accident Data 12
Highway Elements 17
Volume 19
Capacity 24

ANALYSES OF DATA 31

Multiple Linear Regression 31
Intersections 32
Nonintersections 49
Quality Control 67
Intersections 68
Nonintersections 76
Accident Rates 76
Intersections 76
Nonintersections 95
Collision-Condition Diagrams 103
Intersections 103
Nonintersections 111
Other Analyses 113
Hour of Day 113
Day of Week 116
Month of Year 116

TABLE OF CONTENTS (Continued)

Involvement Rates 119
Weather 121
Severity 121
Time Variations 121
Accident Distribution 126
Costs of Accidents 126

RESULTS AND FINDINGS 134

General 134
Multiple Linear Regression 134
Quality Control 135
Accident Rates 136
Collision Diagrams 137
Other Analysis 139

BIBLIOGRAPHY 141

APPENDIX A 143

APPENDIX B 161

APPENDIX C 175

LIST OF TABLES

Table		Page
1.	Intersection Independent Variables	21
2.	Nonintersection Independent Variables	22
3.	Computation of Possible Capacity for a Two-Way Stop Controlled Intersection	29
4.	Independent Variables Used in Final Multiple Linear Regression Analysis - Intersections	33
5.	Dependent Variables - Intersections	34
6.	Coefficients for Multiple Linear Regression Equations - Intersections	35
7.	Simple Correlation Coefficients for Each Variable and all Other Variables - Intersections	42
8.	Variable Means and Standard Deviations - Intersections	47
9.	Independent Variables Used in Final Multiple Linear Regression Analysis - Nonintersections	50
10.	Dependent Variables - Nonintersection	52
11.	Coefficients for Multiple Linear Regression Equations - Nonintersections	53
12.	Simple Correlation Coefficients for Each Variable and All Other Variables - Nonintersections	59
13.	Variable Means and Standard Deviations - Nonintersections	64
14.	Ranking of Intersections by Annual Number of Accidents and Annual Number of Accidents Per Million Vehicles	85
15.	Ranking of Intersections by the Square Theory of Exposure and a Measure of Hazard	89
16.	Ranking of Intersections by Costs of Accidents	92

LIST OF TABLES (Continued)

Table		Page
17.	Ranking of Intersections by Injury Accidents	94
18.	Ranking of Sections by Average Annual Number of Accidents and Several Measures of Exposure	96
19.	Ranking of Sections by a Measure of Hazard and Several Measures of Average Annual Costs of Accidents	99
20.	Ranking of Sections for Injury Accidents by Several Rates .	101
21.	Types of Accidents on the Most Hazardous Nonintersection Study Sections	112
22.	Frequency of Precipitation by Hour of Day for a Ten-Year Period, 1954-1963	122
23.	Number of Days Precipitation Fell and the Amounts of Precipitation in the Lafayette Area by Month and Year	123
24.	Daily Accident Frequency	128
25.	Days of Year Having Three or More Accidents, 1961	129
26.	Days of Year Having Three or More Accidents, 1962	130
27.	Days of Year Having Three or More Accidents, 1963	131
28.	Total Cost of Accidents on U. S. 52 By-Pass, 1961 - 1962 - 1963	133

LIST OF FIGURES

Figure		Page
1.	Populations, Vehicle Miles, Motor Vehicle Registration, Traffic Deaths and Traffic Death Rates for the United States in 1953 and 1963	2
2.	Population, Vehicle Miles, Motor Vehicle Registration, Traffic Deaths and Traffic Death Rates for Indiana in 1953 and 1963	3
3.	Map of Lafayette and West Lafayette, Indiana	6
4.	Development along Portion of the U. S. 52 By-Pass for 1939, 1952 and 1964	7
5.	Investigating Officers Accident Report Form, Side One	13
6.	Investigating Officers Accident Report Form, Side Two	14
7.	Accident Data Punch Card	15
8.	Annual Number of Accidents on U. S. 52 in Fairfield and Wabash Townships from 1956-1964	16
9.	Percentage of all Accidents that Happened within 100, 200 or 500 Feet of an Intersection	18
10.	U. S. 52 By-Pass Study Sections	20
11.	Annual Average Daily Traffic on U. S. 52 By-Pass South of S. R. 26	23
12.	1963 ADT Volume on the U. S. 52 By-Pass and Cross Streets	25
13.	Maneuvering on Paved Shoulder around Left Turn Vehicle	26
14.	Paved Shoulder Available for Use of Through Vehicles	27
15.	Possible Capacity of a Stop-Controlled Cross Street Approach for Major Direction Hourly Volumes on the By-Pass	30
16.	Quality Control Chart for Signalized Intersections, 1961	69

LIST OF FIGURES (Continued)

Figure | Page

17. Quality Control Chart for Signalized Intersections, 1962 . 70
18. Quality Control Chart for Signalized Intersections, 1963 . 71
19. Quality Control Chart for Nonsignalized Intersection, 1961 73
20. Quality Control Chart for Nonsignalized Intersection, 1962 74
21. Quality Control Chart for Nonsignalized Intersection, 1963 75
22. Quality Control Chart for Nonintersection Study Sections, 1-11, 1961 77
23. Quality Control Chart for Nonintersection Study Sections, 12-24, 1961 78
24. Quality Control Chart for Nonintersection Study Sections, 1-11, 1962 79
25. Quality Control Chart for Nonintersection Study Sections, 12-24, 1962 80
26. Quality Control Chart for Nonintersection Study Sections, 1-11, 1963 81
27. Quality Control Chart for Nonintersection Study Sections, 12-24, 1963 82
28. 1963 Accident Spot Map for the U. S. 52 By-Pass 84
29. Average Annual Intersection Accident Rate for 1961, 1962 and 1963 86
30. Relation Between Accident Rate and Intersection ADT 88
31. Average Nonintersection Accident Rates on the U. S. 52 By-Pass for 1961, 1962 and 1963 98
32. Average Annual Accidents Per Million Vehicle Miles by Hour of Day for 1961, 1962 and 1963 114
33. Average Accident Rates by Day of the Week for 1961, 1962 and 1963 117

LIST OF FIGURES (Continued)

Figure | Page

34. Average Accident Rates by Months of Year for 1961, 1962 and 1963 118

35. Involvement Rates for Vehicles by Type, Registration and Direction for 1961, 1962 and 1963 120

36. Average Annual Accident Rate for Clear and Inclement Weather for 1961, 1962 and 1963 124

37. Average Annual Accident Rates by Degree of Severity for 1961, 1962 and 1963 125

38. Average Annual Accident Rates by Weekend, Weekday, Day and Night for 1961, 1962 and 1963 127

39. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Northwestern Ave. 161

40. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Yeager Road 162

41. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Salisbury 163

42. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Happy Hollow 164

43. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Ninth St. Cutoff 165

44. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and S. R. 25 166

45. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Underwood 167

46. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Greenbush 168

47. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Union St. 169

48. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and S. R. 26 170

LIST OF FIGURES (Continued)

Figure | Page

49. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Kossuth 171

50. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and McCarty Lane 172

51. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and S. R. 38 173

52. 1963 ADT Volumes and Turning Movements at U. S. 52 By-Pass and Teal Road 174

The following Figures are in Appendix C and are collision-condition diagrams for intersections on the U. S. 52 By-Pass in 1961, 1962 and 1963.

53. U. S. 52 By-Pass & Northwestern Ave., 1961 176

54. U. S. 52 By-Pass & Northwestern Ave., 1962 177

55. U. S. 52 By-Pass & Northwestern Ave., 1963 178

56. U. S. 52 By-Pass & Yeager Road, 1961 179

57. U. S. 52 By-Pass & Yeager Road, 1962 180

58. U. S. 52 By-Pass & Yeager Road, 1963 181

59. U. S. 52 By-Pass & Salisbury, 1961 182

60. U. S. 52 By-Pass & Salisbury, 1962 A 183

61. U. S. 52 By-Pass & Salisbury, 1962 B 184

62. U. S. 52 By-Pass & Salisbury, 1963 185

63. U. S. 52 By-Pass & Happy Hollow, 1961 186

64. U. S. 52 By-Pass & Happy Hollow, 1962 187

65. U. S. 52 By-Pass & Happy Hollow, 1963 188

66. U. S. 52 By-Pass & Ninth St. Cutoff, 1961 189

67. U. S. 52 By-Pass & Ninth St. Cutoff, 1962 A 190

LIST OF FIGURES (Continued)

Figure		Page
68.	U. S. 52 By-Pass & Ninth St. Cutoff, 1962 B	191
69.	U. S. 52 By-Pass & Ninth St. Cutoff, 1963	192
70.	U. S. 52 By-Pass & S. R. 25, 1961	193
71.	U. S. 52 By-Pass & S. R. 25, 1962	194
72.	U. S. 52 By-Pass & S. R. 25, 1963	195
73.	U. S. 52 By-Pass & Underwood St., 1961	196
74.	U. S. 52 By-Pass & Underwood St., 1962	197
75.	U. S. 52 By-Pass & Underwood St., 1963	198
76.	U. S. 52 By-Pass & Greenbush, 1961	199
77.	U. S. 52 By-Pass & Greenbush, 1962	200
78.	U. S. 52 By-Pass & Greenbush, 1963	201
79.	U. S. 52 By-Pass & Union, 1961	202
80.	U. S. 52 By-Pass & Union, 1962	203
81.	U. S. 52 By-Pass & Union, 1963	204
82.	U. S. 52 By-Pass & S. R. 26, 1961	205
83.	U. S. 52 By-Pass & S. R. 26, 1962	206
84.	U. S. 52 By-Pass & S. R. 26, 1963	207
85.	U. S. 52 By-Pass & Kossuth St., 1961	208
86.	U. S. 52 By-Pass & Kossuth St., 1962	209
87.	U. S. 52 By-Pass & Kossuth St., 1963	210
88.	U. S. 52 By-Pass & McCarty, 1961	211
89.	U. S. 52 By-Pass & McCarty, 1962	212
90.	U. S. 52 By-Pass & McCarty, 1963	213

LIST OF FIGURES (Continued)

Figure Page

91. U. S. 52 By-Pass & S. R. 38, 1961 214

92. U. S. 52 By-Pass & S. R. 38, 1962 215

93. U. S. 52 By-Pass & S. R. 38, 1963 216

94. U. S. 52 By-Pass & Teal Road, 1961 217

95. U. S. 52 By-Pass & Teal Road, 1962 A 218

96. U. S. 52 By-Pass & Teal Road, 1962 B 219

97. U. S. 52 By-Pass & Teal Road, 1963 220

ABSTRACT

Peterson, Arvid Odean. MSCE, Purdue University, August, 1965. An Analysis of Traffic Accidents on a High-Volume Highway. Major Professor: Harold L. Michael.

The major objective of this study was to contribute to a factual basis on which recommendations for traffic engineering improvements could be made for the U. S. 52 By-Pass at Lafayette-West Lafayette, Indiana. To achieve this objective, each accident resulting in $50 or more property damage, an injury or a death on the by-pass or within 200 feet of the by-pass on intersecting streets in the period January 1, 1961, through December 31, 1963, was analyzed in depth.

The 834 accidents involving 374 injuries and ten deaths were analyzed by multiple linear regression analysis and quality control techniques. Several different types of accident rates were computed and evaluated and collision-condition diagrams were utilized to determine specific causes of accidents at intersections and nonintersection study sections. In addition accident rates for weekend vs. weekday, day vs. night and clear vs. inclement weather were compared. These were but a few of the comparisons made in the analysis of data.

Although this study has only been of one seven-mile high-accident facility, the findings may be of considerable value on similar facilities in other locations.

INTRODUCTION

In the United States (1)* and in Indiana (12) the population, the number of vehicle miles, the number of motor vehicle registrations, and the number of deaths from traffic accidents, 1953 to 1963, have increased as shown in Figures 1 and 2. However, the death rate per 100 million vehicle miles has decreased substantially. The highway engineer is the first to admit that, although successful steps have been taken to reduce motor vehicle accidents, there is room for much improvement. The Joint Highway Research Project in 1964 initiated a Traffic Engineering Demonstration Project on the U. S. 52 By-Pass at Lafayette-West Lafayette, Indiana. One of the first phases of this study was a study in depth of the traffic accidents which occurred on this facility so that recommendations could be made for traffic engineering improvements which would reduce accidents on this facility.

A study was also made of the delays on the by-pass and the results of that study are being submitted in another research report. Although this study has only been of one seven-mile high-accident facility, the findings and subsequent recommendations may be of considerable value on similar facilities in many locations.

The Lafayette-West Lafayette By-Pass was the scene of 834 accidents between January 1, 1961, and December 31, 1963. A total of 374 injuries and ten deaths resulted from these accidents. These are the accidents which were investigated in this study.

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* The numbers in parentheses refer to numbers in the bibliography.

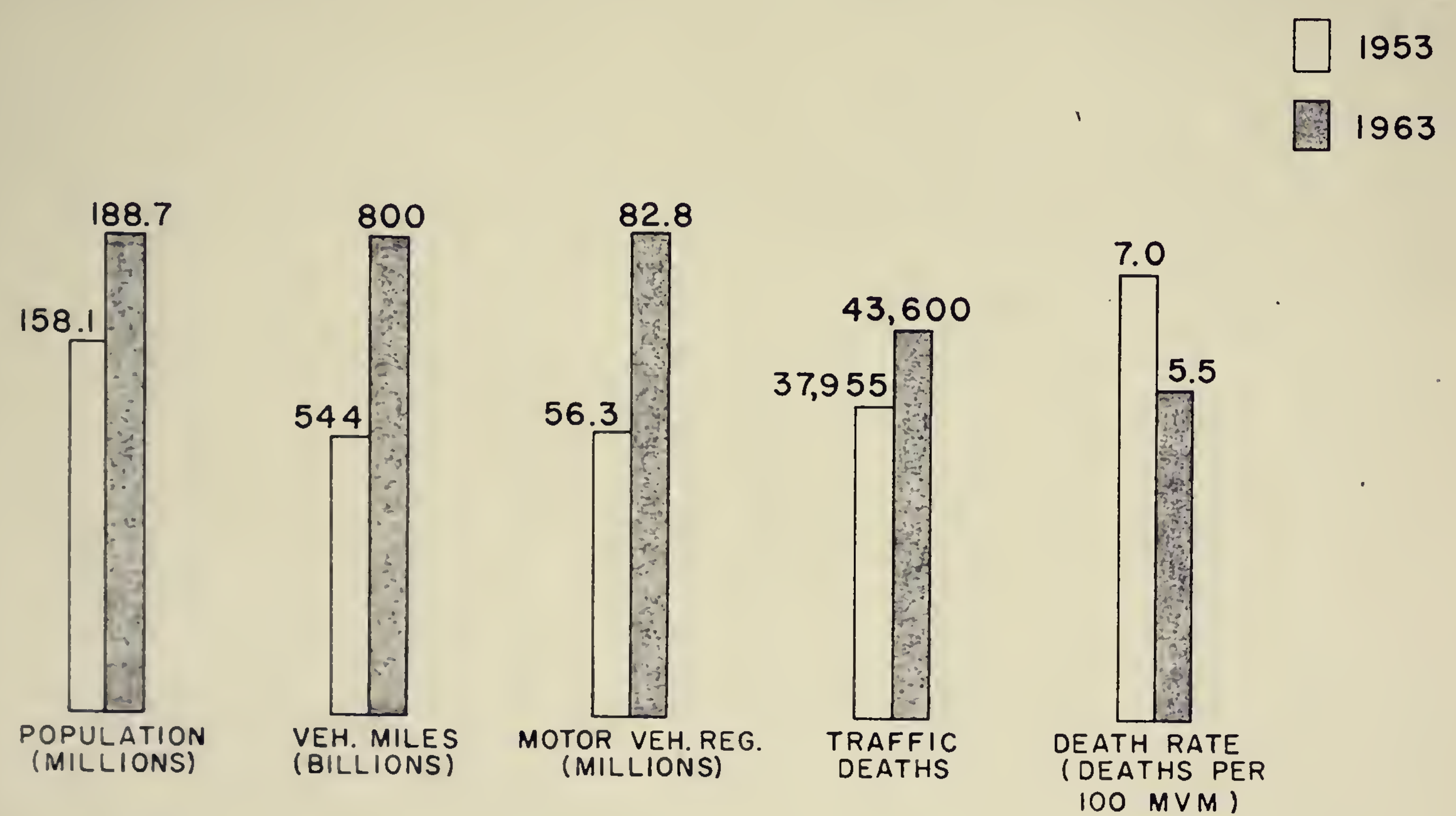

FIG. 1 – POPULATIONS, VEHICLE MILES, MOTOR VEHICLE REGISTRATION, TRAFFIC DEATHS AND TRAFFIC DEATH RATES FOR THE UNITED STATES IN 1953 AND 1963.

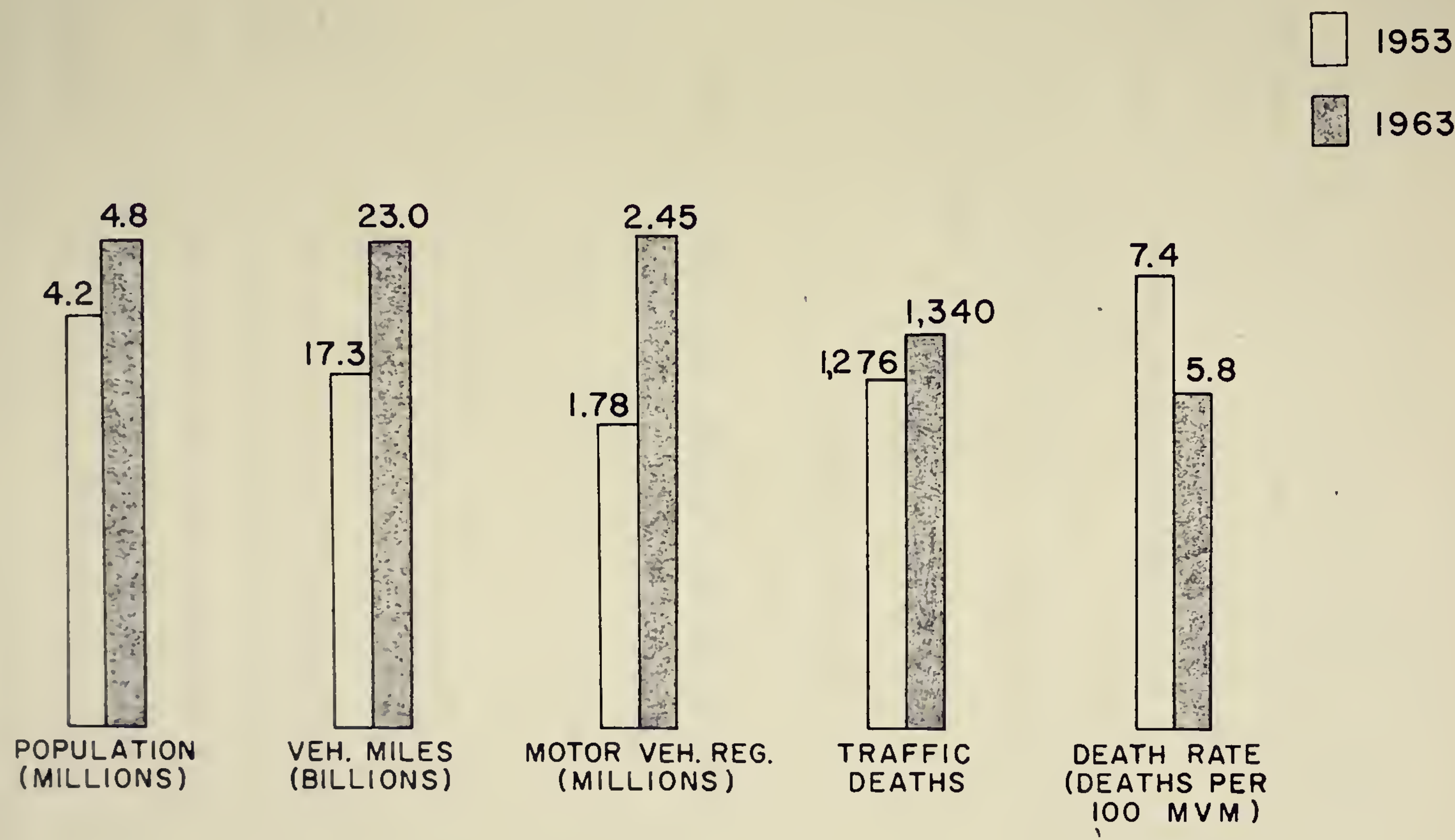

FIG. 2 – POPULATION, VEHICLE MILES, MOTOR VEHICLE REGISTRATION, TRAFFIC DEATHS AND TRAFFIC DEATH RATES FOR INDIANA IN 1953 AND 1963.

PURPOSE

The major objective of this study was to contribute to a factual basis on which recommendations for traffic engineering improvements could be made for the U. S. 52 By-Pass at Lafayette-West Lafayette, Indiana. To achieve this objective, each accident resulting in $50 or more property damage, an injury or a death on the by-pass or within 200 feet of the by-pass on intersecting streets in the period January 1, 1961, through December 31, 1963, was analyzed in depth.

THE STUDY LOCATION

The location of this study was the U. S. 52 By-Pass at Lafayette, Indiana. The combined population of Lafayette and West Lafayette is approximately 55,000. This does not include approximately 15,000 Purdue University students.

Traffic using this facility is through, terminal or local in nature. Since the by-pass is on a direct route between Chicago and Indianapolis, commercial vehicles represent approximately fourteen percent of daylight traffic and a much higher percentage during hours of darkness. Through trips constitute less than fifty percent of the travel.

A large percentage of the traffic terminates in Lafayette, an industrial center and the county seat of Tippecanoe County, or in West Lafayette at Purdue University. A portion of the traffic is local, seeking access to commercial and industrial establishments located on the by-pass.

The by-pass was constructed in 1938 in a rural area around the two cities. Since then development has occurred on both sides of the facility until much of the by-pass resembles an urban arterial.

The location of the U. S. 52 By-Pass in relation to the two cities is shown in Figure 3. A portion of the facility with the extensive development along it is shown in Figure 4.

PREVIOUS INVESTIGATIONS

The research material available on the subject of motor vehicle accidents is voluminous. This review of literature has been restricted to a few examples of investigations which used multiple linear regression or quality control analysis and one recent investigation which studied the effectiveness of traffic engineering improvements.

Multiple Linear Regression

A study by Woo (22) on rural Indiana highways indicated that accident occurrences were related to the ADT and the total number of entrances per mile for certain volume ranges of traffic. Prediction equations appeared to be more reliable for ADT's over 8,000 showing only a + 3 percent error of estimate. Accidents per mile was used as the rate since accidents per million vehicle miles showed little relationship with the roadway factors. Significant factors were ADT, congestion index, lane width and total entrances per mile.

In 1949, the Michigan State Highway Department reported the results of an accident analysis for 1948 and 1949 (11). Although the study

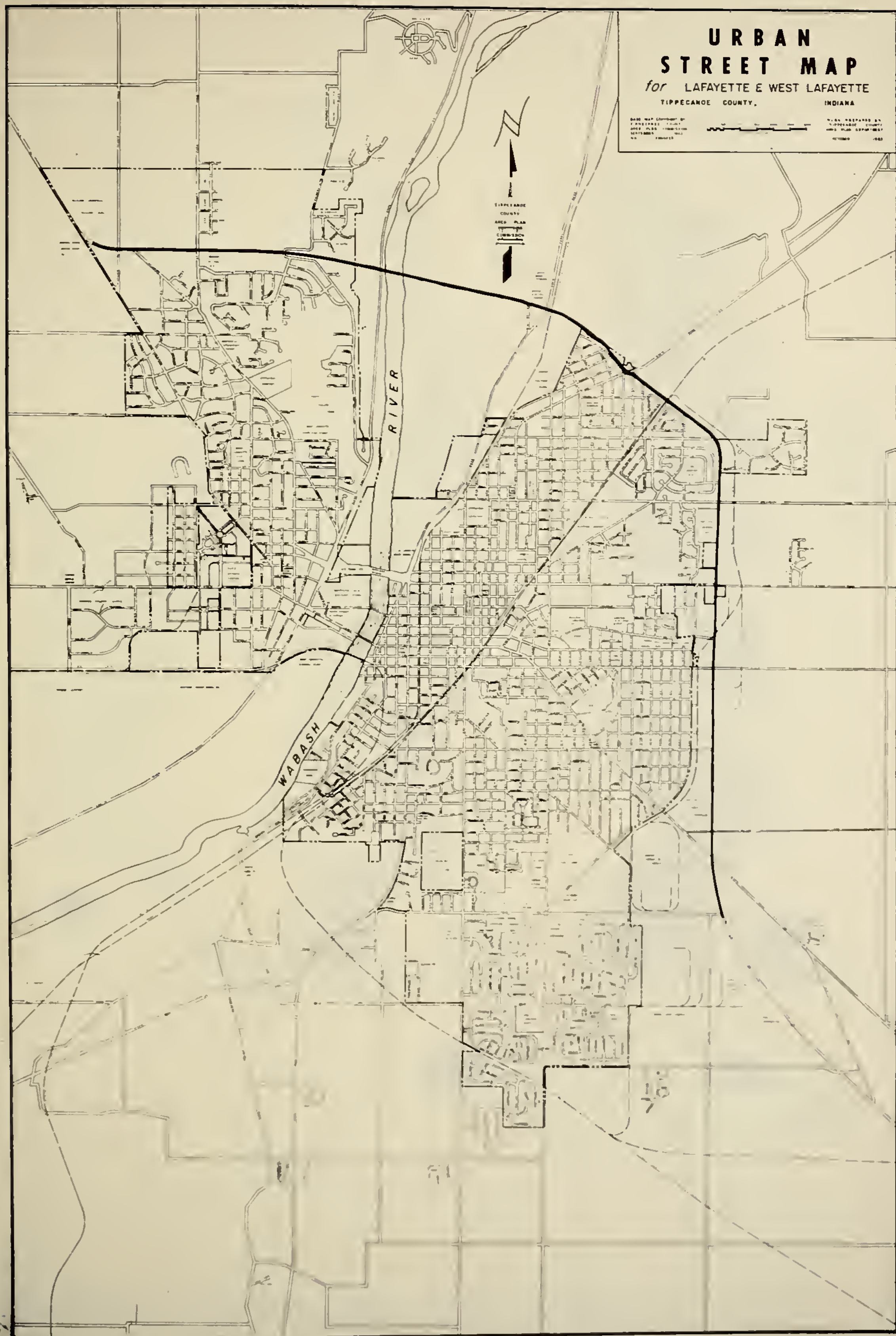

FIGURE 3 MAP OF LAFAYETTE AND WEST LAFAYETTE INDIANA.

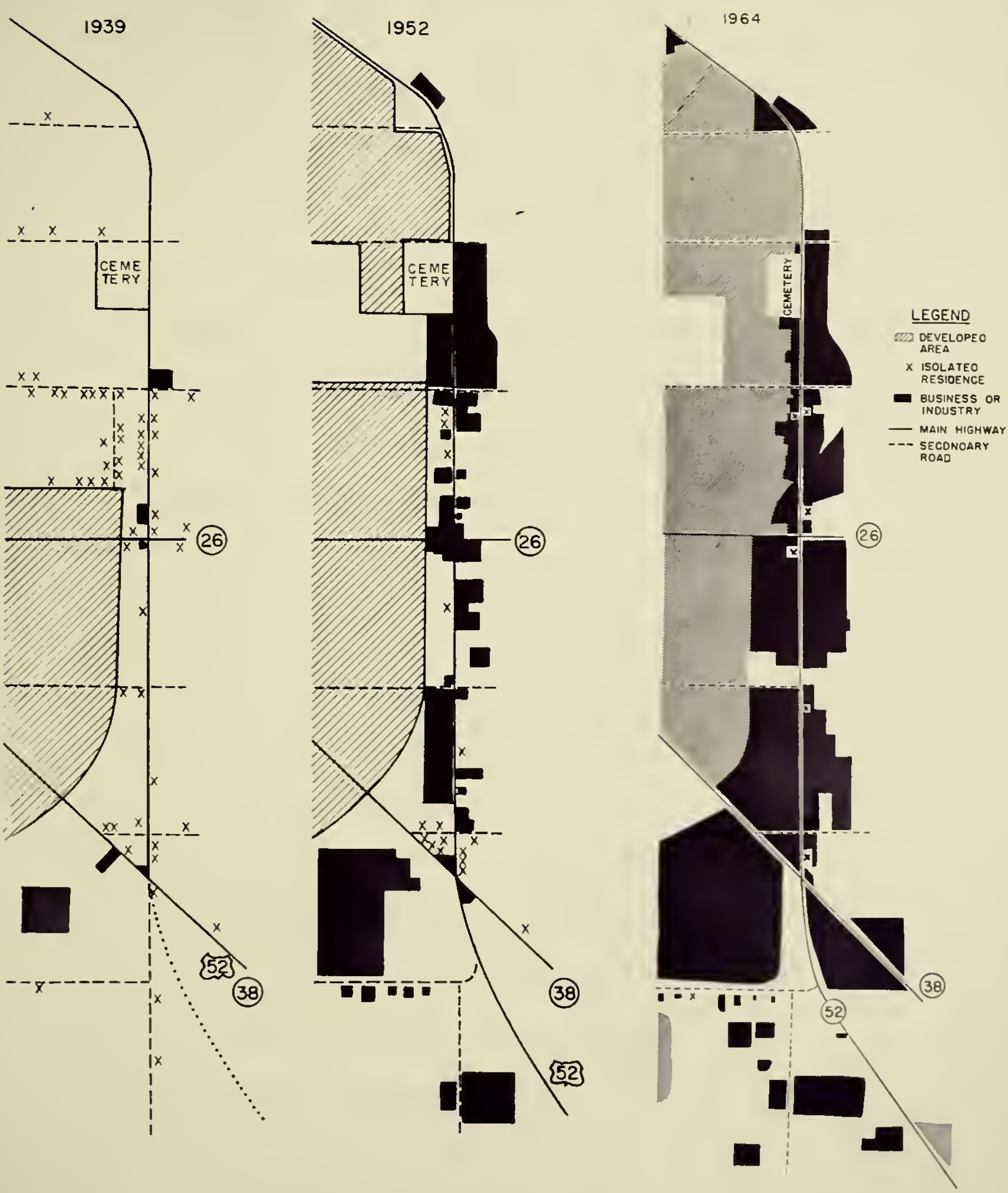

FIGURE 4 DEVELOPMENT ALONG PORTION OF THE U.S. 52 BY-PASS FOR 1939, 1952 AND 1964.

emphasized the importance of intersections and accidents, it was found to be difficult to determine any relationship between individual features at intersections and accidents.

A study by J. Al Head, Oregon State Highway Department, in 1955 (9) resulted in the following conclusions:

"1. Motor vehicle accident rates are related to certain physical features of urban extensions of the highway system. This relationship is strong enough in the higher ADT ranges to make it possible to predict accident rates with a reasonable degree of accuracy on the basis of known physical features.

2. Accident rates on low volume roads do not have a strong relationship with any roadway feature.

3. Motor vehicle accident rates increase when:

    a. Number of commercial units adjacent to the section increases.

    b. Number of traffic signals increases.

    c. Number of intersections increases.

    d. Indicated speed decreases.

    e. Average daily traffic increases.

    f. Pavement width increases."

Quality Control

In 1955 Norden, Orlansky and Jacobs (16) concluded that the application of statistical quality-control techniques for analyzing highway-accident data showed strong promise in contributing substantially in solving the highway accident problem.

A study by Blindauer (3) involving high-accident-rate locations in Indiana in 1954-55 concluded that the application of the principle of quality control to the analysis of traffic accidents was very useful in locating accident-prone sections of a highway, especially those containing single intersections, structures and railroad crossings. Assignable causes were found for 75 percent of the sections that were out of control in this study.

Traffic Engineering Improvements

The Bureau of Public Roads with the cooperation of the District of Columbia Department of Highways and Traffic in 1959 undertook a study to determine the theoretical effectiveness of various known methods of increasing traffic capacity on an urban arterial (6). Improvements were placed into one of three basic phases, depending upon the complexity of the proposal and the expense involved, as follows:

Phase 1: Those possible at relatively little or no cost.

Phase 2: Those requiring moderate expenses.

Phase 3: Those requiring major expenditures and construction.

The following improvements were recommended for each of the three phases.

Among the recommendations for improvements in Phase 1 were:

1. Educate drivers to signal all turns well in advance to reduce the unnecessary serious back-ups which were observed to develop frequently behind vehicles which suddenly turned without signaling.

2. Adopt spot turning-movement controls to alleviate special current problems at several intersections.
3. Install lane markings on the existing street to make full use of the pavement between the curbs.
4. Prohibit left turns into and out of minor intersecting streets where such turning movements are few in number yet interfer with through traffic.
5. Control turning movements in midblock into driveways and offstreet parking areas, though they need not be eliminated except in special cases.
6. Retime the traffic signals to establish the best possible progression, once the foregoing steps have established a more orderly and predictable flow.

Some improvements for Phase 2 were:

1. Widen narrow bottleneck sections where possible.
2. Install a modern, flexible progressive signal system.
3. Channelize several major at-grade intersections. In most cases, some widening would be involved.
4. Resurface the entire street, generally within the existing curb lines.
5. Provide a complete system of lane markings.
6. Install a modern lighting system.

Two Phase 3 improvements were:

1. Grade separations at certain major intersections and widening wherever possible are required or at least desirable. In practice, these improvements may not function efficiently unless corresponding

improvements are made on a few connecting streets to prevent those streets from becoming overloaded.

2. Median dividers are desirable, but their acceptability to proprietors of fronting businesses should be firmly established before they are installed.

PROCEDURE

Accident Data

A three year study period was chosen in order that an adequate sample of accidents could be obtained. The last three years of accident data available were 1961 - 1963. Therefore, the study dates were chosen to include the period of January 1, 1961 through December 31, 1963.

Most of the accident data were collected from the Accident Records Division of the Indiana State Police. Indiana state law requires that all accidents involving a personal injury, death or property damage of $50 or more be reported to the police. Some of the accident information was obtained from the files of the Lafayette police, West Lafayette police and Indiana State Police Post No. 3 at Lafayette.

The accident information on the investigating officer's accident report form (Figure 5 and 6) was available from the Accident Records Division in coded form (Figure 7). The heading of the punch card listed the data coded into each column. The codes and the information available on the punch cards are given in Appendix A. The punch cards for the accidents on U. S. 52 in Fairfield and Wabash Townships were obtained. The increasing annual number of these accidents is shown in Figure 8 .

Information which was desired but which was not coded included whether the vehicle was turning right or left, the direction of travel before the accident, the exact location of the accident and the addresses

Mail Report To: INDIANA STATE POLICE, INDIANAPOLIS 4, INDIANA

DO NOT WRITE IN THIS SPACE

(8) TYPE ______ (9) SOURCE ______ (10-11) ANALYSIS ______ (12-13-14-15) LOSS ______ (16) LOCATION ______ (2-3-4-5-6-7) ACCIDENT NO. ______

TIME

(17-18) (19-20) (21) (22) (23-24)

DATE OF ACCIDENT ______ Month Day Year DAY OF WEEK ______ TIME OF DAY ___:___ AM ___:___ PM

LOCATION

(25-26) (27) (28-29)

PLACE WHERE ACCIDENT OCCURRED: COUNTY ______ CITY OR TOWN ______

If accident occurred outside of city limits, indicate distance from nearest city or town limits, using two directions, if necessary. (30-31)

TOWNSHIP ______

______ Occurred within corporate limits. ______ MILES NORTH. ______ MILES SOUTH. ______ MILES EAST. ______ MILES WEST OF.

______ Occurred outside corporate limits. LIMITS OF ______ City or Town

(32-33-34) (35-36) (37-38-39-40)

ROAD ON WHICH ACCIDENT OCCURRED ______ Name of Street or No. of Highway (US or STATE). If no No., use name. AT IT S INTERSECTION WITH ______ Name or Number of Intersecting Street or Highway.

IF NOT AT INTERSECTION ______ FEET (___N ___S ___E ___W) OF ______ Show nearest intersection, house number, or other identifying landmark.

DO NOT MARK IN BOXES

VEHICLES

Total Number of Vehicles Involved

VEHICLE NUMBER 1: (41) (42-43)

YEAR ______ MAKE ______ TYPE ______ Sedan, Truck, Bus, etc. (44)

LICENSE PLATE ______ Number State Year

DRIVER ______ (Print) Last Name First Middle

ADDRESS ______ (Print) Street or R.F.D. (45-46) (47)

______ City and State BIRTH DATE ______ AGE ______ SEX ______ (48)

DRIVER'S LICENSE ______ Number State Type (49)

OWNER ______ Last Name First Middle

ADDRESS ______ Street or R.F.D. City State

PARTS OF VEHICLE DAMAGED ______

ESTIMATE OF REPAIR $ ______

VEHICLE REMOVED TO ______ BY ______

VEHICLE NUMBER 2: (41) (42-43)

YEAR ______ MAKE ______ TYPE ______ Sedan, Truck, Bus, etc. (44)

LICENSE PLATE ______ Number State Year

DRIVER ______ (Print) Last Name First Middle

ADDRESS ______ (Print) Street or R.F.D. (45-46) (47)

______ City and State BIRTH DATE ______ AGE ______ SEX ______ (48)

DRIVER'S LICENSE ______ Number State Type (49)

OWNER ______ Last Name First Middle

ADDRESS ______ Street or R.F.D. City State

PARTS OF VEHICLE DAMAGED ______

ESTIMATE OF REPAIR $ ______

VEHICLE REMOVED TO ______ BY ______

INJURED

Total Number Killed (50)

Injured (51)

(52)

(53-54) (55)

NAME ______ (Print) Last Name First Middle AGE SEX

ADDRESS ______ (56) Street or R.F.D. City (57) State

DRIVER ______ PASSENGER ______ IN VEHICLE NUMBER ______

PEDESTRIAN ______ Other (EXPLAIN) ______

NATURE AND EXTENT OF INJURIES ______

(53-54) (55)

NAME ______ (Print) Last Name First Middle AGE ______ SEX ______

ADDRESS ______ (56) Street or R.F.D. City (57) State

DRIVER PASSENGER IN VEHICLE NUMBER ______

PEDESTRIAN Other (EXPLAIN) ______

NATURE AND EXTENT OF INJURIES ______

Mark First One That Applies (58)

1. ___	2. ___	3. ___	4. ___
Died as result of accident.	Visible signs of injury, as bleeding wound, distorted limb or had to be carried away.	Other visible injuries, as bruises, swelling, abrasions, limping, etc.	No visible injuries, but complaint of pain or momentary unconsciousness.

1.	2.	3. ___	4. ___
Died as result of accident.	Visible signs of injury, as bleeding wound, distorted limb or had to be carried away.	Other visible injuries, as bruises, swelling, abrasions, limping, etc.	No visible injuries, but complaint of pain or momentary unconsciousness.

DAMAGE TO OTHER PROPERTY ______ Name of Object (s) Owner's Name and Address Nature of Damages

______ ESTIMATE OF REPAIR $ ______

This form is approved by the Superintendent, Indiana State Police, pursuant to Burns Indiana Statutes 47-1918, Acts 1939, Ch. 48.

FIGURE 5 INVESTIGATING OFFICERS ACCIDENT REPORT FORM, SIDE ONE.

(59) CHEMICAL TEST
Driver 1 2 / Ped. (Check one)

0___ ___ ___ No test offered
1___ ___ ___ Test offered but refused.
2___ ___ ___ Breath test given.
3___ ___ ___ Blood test given.
4___ ___ ___ Urine test given.

(60) ARREST—(Check one)
Driver 1 2

0___ ___ Not arrested.
1___ ___ Arrested for D. U. I.
2___ ___ Arrested for other violation

(61) SPEED LIMIT ________ **MPH**

(62) SPEED BEFORE ACCIDENT
Veh 1 ______ MPH   Veh 2 ______ MPH

(63) CONTRIBUTING CIRCUMSTANCES INDICATED
Driver 1 2

1___ ___ Speed too fast.
2___ ___ Failed to yield right-of-way
3___ ___ Drove left of center.
4___ ___ Improper overtaking.
5___ ___ Passed stop sign.
6___ ___ Disregarded traffic signal.
7___ ___ Followed too closely
8___ ___ Made improper turn
9___ ___ Other improper driving
10___ ___ Inadequate brakes
11___ ___ Improper lights.
12___ ___ Had been drinking

(64) VEHICLE DEFECTS
Driver 1 2

0___ ___ No defects.
1___ ___ Brakes defective.
2___ ___ Lights defective
3___ ___ Defective steering
4___ ___ Puncture or blowout.
8___ ___ Other defects

(65) VISION OBSCURED
Driver 1 2

0___ ___ Not obscured.
1___ ___ By building s.
2___ ___ By embankment.
3___ ___ By signboard
4___ ___ Trees, crops, etc
5___ ___ By hillcrest
8___ ___ ________

________ (Specify other)

INDICATE ON THIS DIAGRAM WHAT HAPPENED **DRAW DIAGRAM TO SCALE**

Indicate North by arrow

DESCRIBE WHAT HAPPENED:
Refer to vehicle by number ________

WHAT DRIVERS WERE GOING TO DO BEFORE ACCIDENT:
(66)

Driver No 1 was headed ___ N ___ S ___ E ___ W on ________
(Name or number of street or highway)

Driver No 2 was headed ___ N ___ S ___ E ___ W on ________
(Name or number of street or highway)

(Check applicable items for each driver.)

Driver 1 2		Driver 1 2		Driver 1 2	
				5___ ___	Start from parked position.
0___ ___	Passing	2___ ___	Backing.	6___ ___	Avoiding veh., obj., ped.
1___ ___	Turn right.	3___ ___	Slow or stop	7___ ___	Skidded before applying brakes.
1___ ___	Turn left	4___ ___	Going straight ahead.	8___ ___	Skidded after applying brakes.
1___ ___	Make U turn	5___ ___	Start in traffic lane	9___ ___	Parked

CONDITION OF DRIVERS AND PEDESTRIANS
(Check one)

(68) (70)
Driver 1 2 / Ped.

0___ ___ ___ Had NOT been drinking.
1___ ___ ___ Obviously drunk.
2___ ___ ___ Ability impaired.
3___ ___ ___ Ability not impaired.
4___ ___ ___ Unknown if impaired.

(69) (71)

11___ ___ ___ Apparently normal.
0___ ___ ___ Eyesight defective.
1___ ___ ___ Hearing defective.
2___ ___ ___ Other defects.
3___ ___ ___ Illness.
4___ ___ ___ Fatigued.
5___ ___ ___ Apparently asleep.
6___ ___ ___ Attention diverted
7___ ___ ___ Advanced senility.
8___ ___ ___ Other handicaps.

________ (Specify other handicaps)

WHAT PEDESTRIAN WAS DOING BEFORE ACCIDENT

(67)
Pedestrian was going ___ N ___ S ___ E ___ W ___ along / ___ across or into ________
Street or Highway

From ________ to ________
(N. E. corner to S. E. corner or from West side to East side, etc.)

(Check one)

0	Not in roadway	6___	Other working in roadway.
1	Walking in roadway with traffic.	7___	Playing in roadway
2	Walking in roadway against traffic	8___	Other ________ (Specify actions)
3	Pushing or working on vehicle	11	Crossing or entering not at intersection.
4	Getting on or off vehicle	12	Crossing or entering at intersection.
5	Standing in roadway		

ROAD

(72) TRAFFIC CONTROL

Driver 1 2		Driver 1 2	
0___ ___	Police officer.	4___ ___	Other lane markings
1___ ___	Automatic signal.	5___ ___	Stop sign
2___ ___	Yield right-of-way sign	6___ ___	Warning sign or signal
3___ ___	Center line marked.	7___ ___	No passing zone
		8___ ___	All others

(73) CHARACTER (74) (Check two)
1 Straight
2 Curve
1___ Level
2___ On grade
3___ Hillcrest

(76) SURFACE (Check one)
1___ Concrete
2___ Blacktop
3___ Sand or dirt
4___ Gravel
8___ ________ Other

(75) CONDITION (Check one)
1___ Dry
2___ Wet.
3___ Snow/ice
8___ ________ Other

(77) WEATHER (Check one)
1___ Clear
2___ Raining
3___ Snowing
4___ Fog
8___ ________ Other

(78) LIGHT (Check one)
1___ Daylight.
2___ Dark.
3___ Dawn or dusk.

(79) KIND OF LOCALITY (Check one to show that area adjacent to roadway for 300' was primarily:)
1___ School or playground.
2___ Industrial or business.
3___ Residential.
4___ Open country

(88) ROAD DEFECTS
1___ Foreign material on surface
2___ Loose sand, gravel, etc.
3___ Holes, ruts, dips, bumps, etc.
4___ Defective shoulders
5___ Obstruction not lighted or signaled.
6___ Standing water, landslide, etc.
7___ Obstructed by previous acc.
8___ All other defects

WITNESSES
Name ________ Address ________ Location ________
Name ________ Address ________ Location ________

POLICE ACTION
ARRESTS: Name ________ Charge ________
Name ________ Charge ________

INVESTIGATION: Time notified of accident ________ AM ________ PM Time of arrival at the scene ________ AM ________ PM
Where else was investigation made? ________ Is investigation complete? ___ Yes ___ No
Were photographs taken? ___ Yes ___ No Driver report form furnished to ___ driver No. 1 ___ driver No. 2

***SIGNATURE** ________ Department ________ Date of report ________

ARB 2 Investigator's Report Rev. 60

FIGURE 6 INVESTIGATING OFFICERS ACCIDENT REPORT FORM, SIDE TWO.

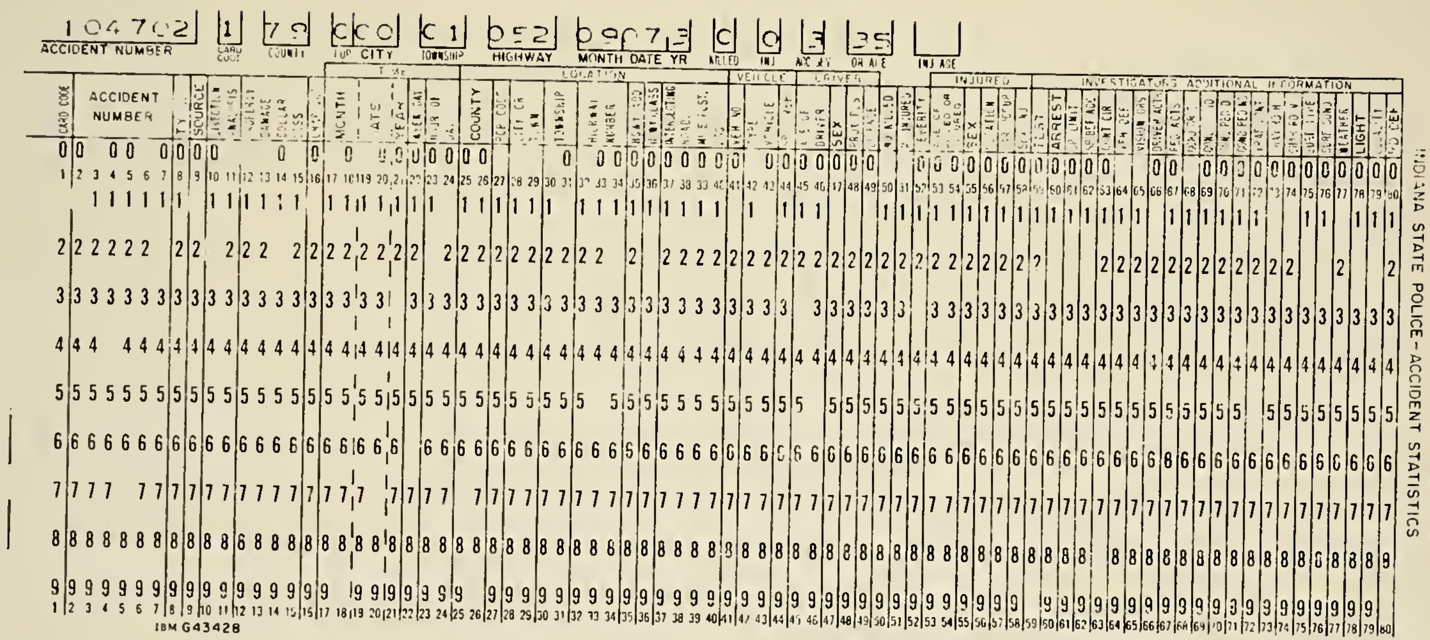

FIGURE 7 ACCIDENT DATA PUNCH CARD.

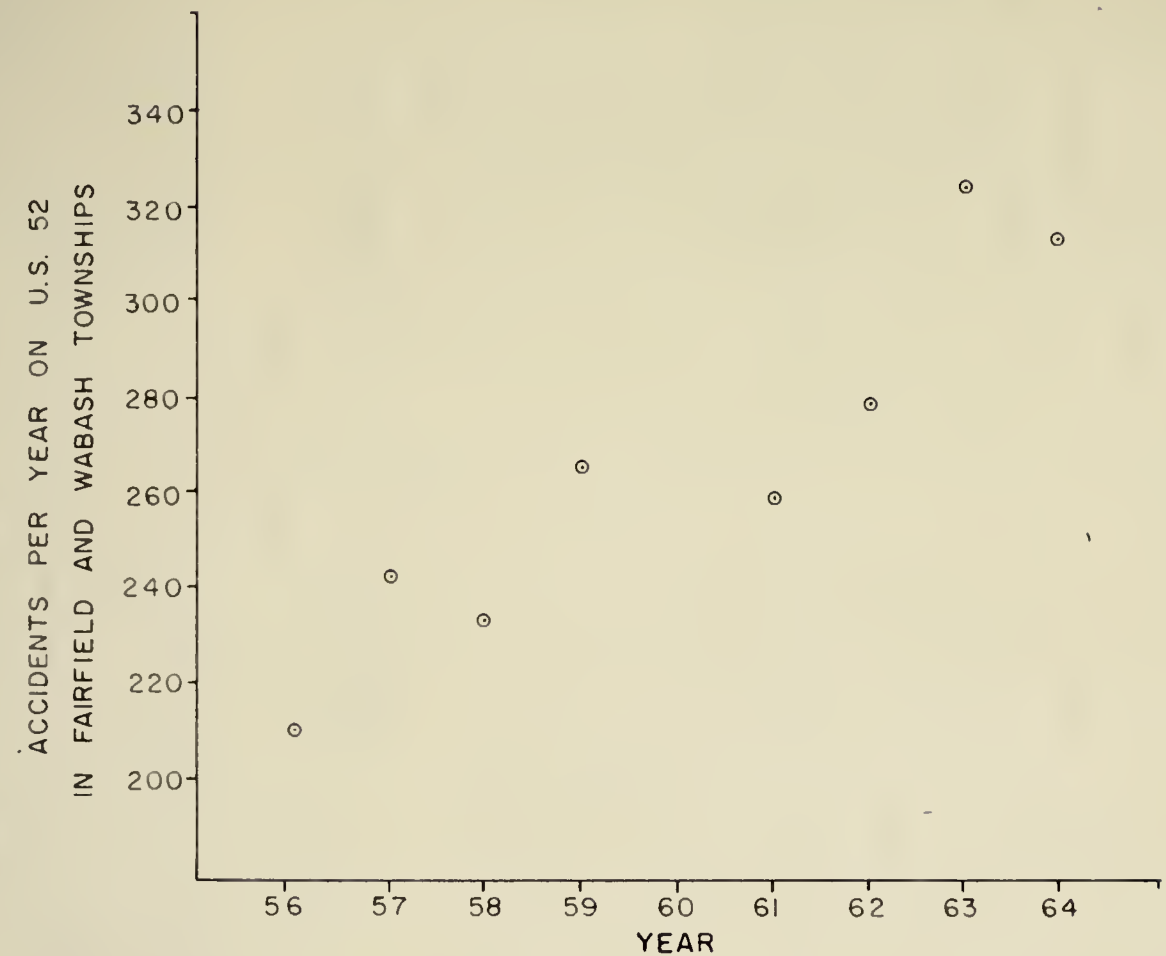

FIGURE 8 ANNUAL NUMBER OF ACCIDENTS ON U.S. 52 IN FAIRFIELD AND WABASH TOWNSHIPS FROM 1956–1964.

of the drivers. This information was obtained from the original accident reports and placed on the same punch card along with the previously coded information. By use of the detailed location on the original accident report, the by-pass accidents were separated from the other accidents occurring on U. S. 52 in Fairfield and Wabash Townships.

Preliminary study indicated that of all accidents approximately 56.7 percent happened within 100 feet of an intersection while about 65.1 percent happened within 200 feet of an intersection (see Figure 9). An additional 300 feet gave an increase of only 10 percent. Also at a distance greater than 200 feet most of the accidents were influenced by factors other than intersection characteristics. Therefore, all accidents which happened within 200 feet of each intersection on the cross streets were included in the study, and accidents within 200 feet of each intersection on the by-pass and the cross streets were analyzed as intersection accidents. Data on accidents occurring on the cross streets within 200 feet of the by-pass were obtained from local police records and coded in the same manner as the U. S. 52 By-Pass accidents.

A collision diagram was drawn for each accident.

Highway Elements

The by-pass study section extended from the northwest corner of West Lafayette to the southeast corner of Lafayette. With the aid of aerial photographs and field inspection the by-pass was divided into sections. Each section was selected so that it would have similar physical characteristics, commercial development, and volume of traffic throughout its length.

Fourteen intersections were considered to have a large enough cross street volume to warrant consideration as an intersection study section.

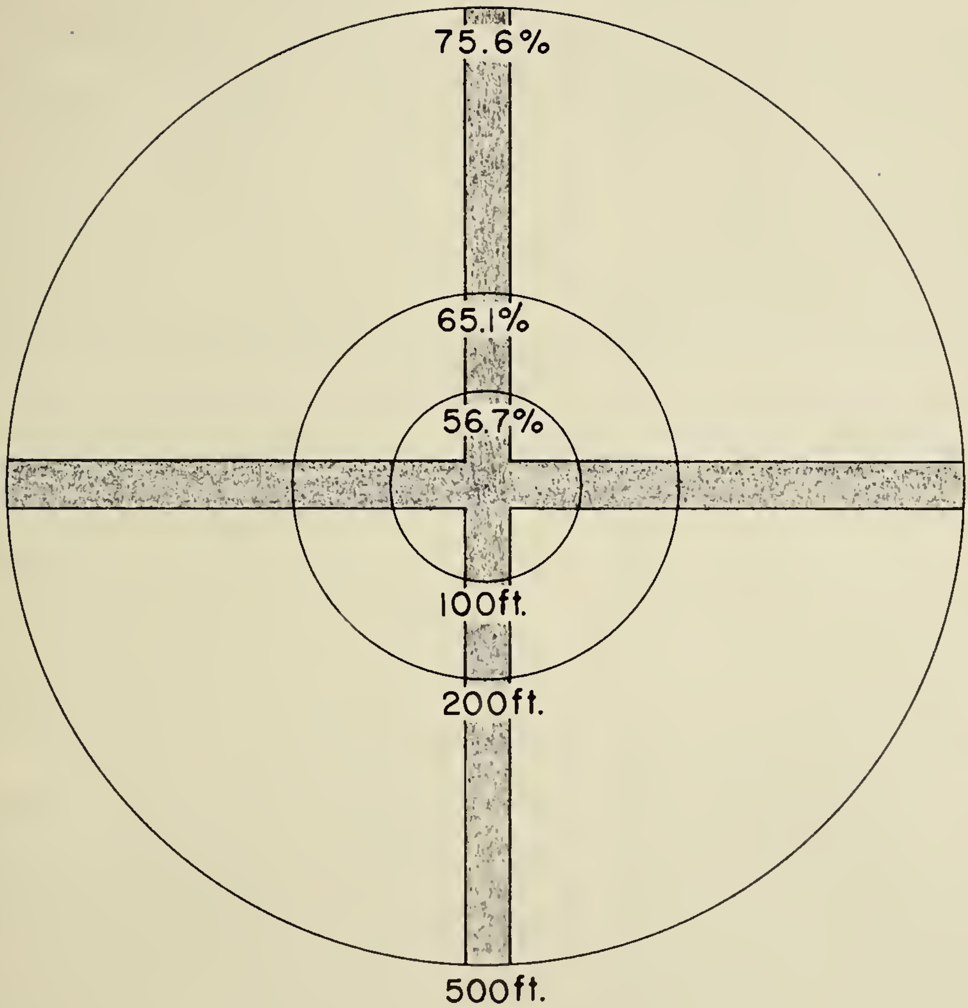

FIGURE 9 PERCENTAGE OF ALL ACCIDENTS THAT HAPPENED WITHIN 100, 200 OR 500 FEET OF AN INTERSECTION.

A few other intersections with low cross street volumes (below 500 ADT) were considered within the section in which they occurred. The by-pass was divided into twenty-four sections and fourteen intersection study areas. These sections are illustrated in Figure 10.

An inventory of the physical features of each section was conducted in the summer of 1964. Those highway characteristics (variables) which might affect accident rates and which were considered in the analysis of each section are shown in Tables 1 and 2. Physical conditions that changed during the three year period were determined by consulting the Traffic Division of the Crawfordsville District, Indiana State Highway Commission. The Lafayette-West Lafayette City Directory was used to determine the year each commercial establishment was developed along the by-pass.

Volume

In many accident studies volume has correlated well with accidents. Volume has been usually represented by annual average daily traffic (ADT). In this study the hourly volume at the time of the accident as well as the ADT was correlated with the accident occurrence. Because volume counts were not taken during the study period, these hourly volumes were estimated as indicated in the following paragraphs.

Traffic counts taken during the summer of 1964 were supplemented by volume data from the Division of Planning, Indiana State Highway Commission (see Figure 11 for ADT volume data at one point on the by-pass). Factors were determined from the count data on the by-pass and from records of the Highway Commission for yearly, monthly, daily, and hourly variations in

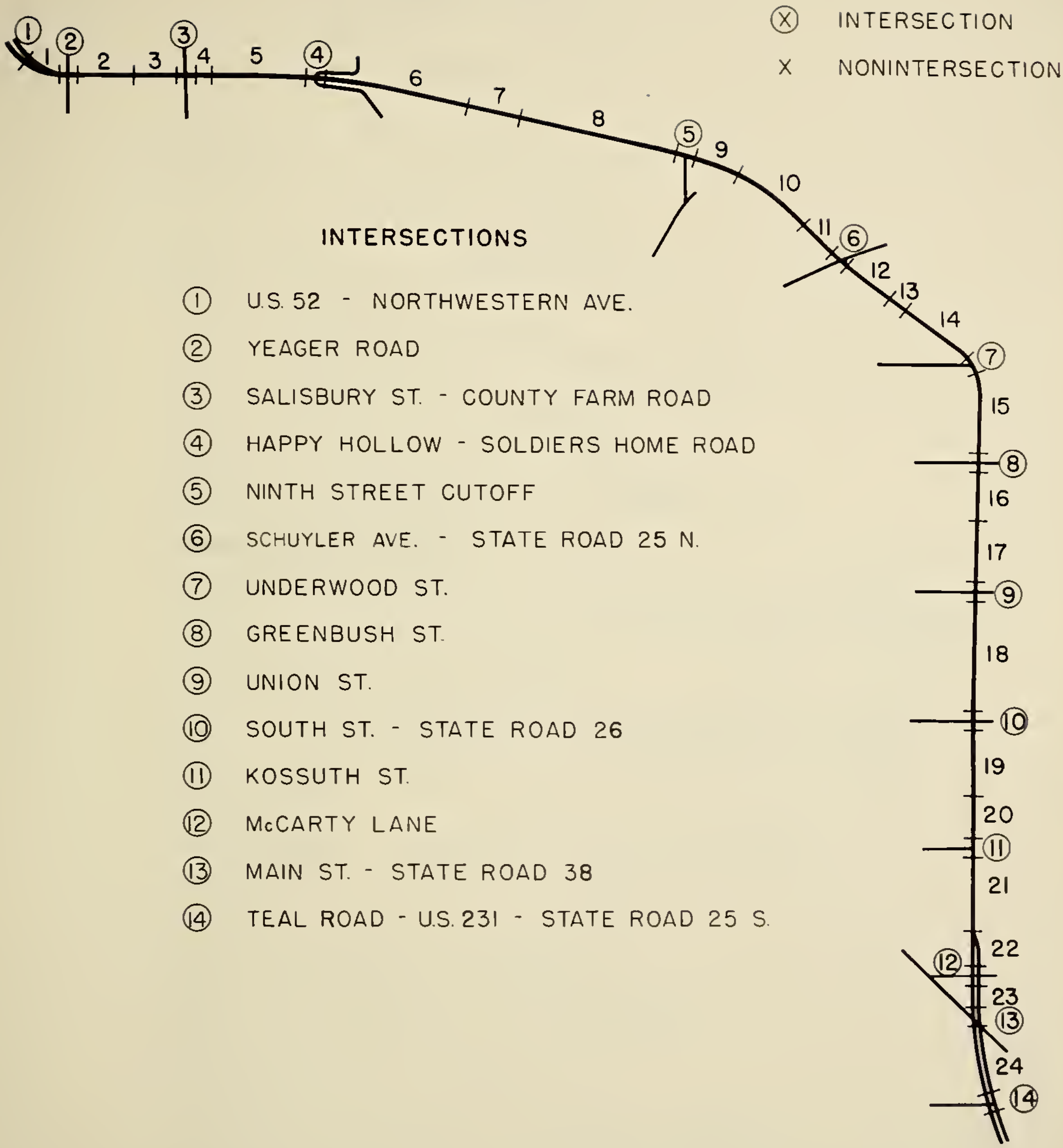

FIGURE 10 U.S. 52 BY-PASS STUDY SECTIONS.

TABLE 1

INTERSECTION
INDEPENDENT VARIABLES

Number	Variable
1	Presence of traffic signal
2	Percent green time on by-pass
3	By-pass ADT, vehicles per day
4	Cross street ADT, vehicles per day
5	Total ADT, vehicles per day
6	Total hourly practical capacity, vehicles per hour
7	Number of right turn only lanes
8	Number of left turn only lanes
9	Length of extra approach turn lanes, feet
10	Length of extra exit lanes, feet
11	Maximum percent left turns from by-pass, percent*
12	Maximum percent left turns from cross street, percent*
13	Maximum approach speed, mph**
14	Number of intersections from extremities of by-pass
15	Total number of establishments within 200 feet of intersection
16	Total number of driveways within 200 feet of intersection
17	Percent of grade, absolute value
18	Degree of curvature, degrees
19	Number of approaches to intersection
20	Number of lanes on by-pass
21	Total width of driveways, feet
22	Maximum percent right turns from by-pass*
23	Maximum percent right turns from cross street*
24	Total approach width for intersection, feet
25	Distance from extremities of by-pass, feet
26	Number of extra exit lanes
27	Number of extra approach lanes

* Highest of the percent turns during all daylight hours for the two directions of flow.

** Highest of the average speeds on the approaches to an intersection.

TABLE 2

NONINTERSECTION
INDEPENDENT VARIABLES

Number	Variable
1	Number of establishments per mile (side toward urban area)
2	Number of establishments per mile (side opposite urban area)
3	Total number of establishments per mile
4	Number of driveways per mile (side toward urban area)
5	Number of driveways per mile (side opposite urban area)
6	Total number of driveways per mile
7	Shoulder width (side toward urban area), feet
8	Shoulder width (side opposite urban area), feet
9	Total shoulder width (both sides), feet
10	Number of low volume intersections per mile (side toward urban area)
11	Number of low volume intersections per mile (side opposite urban area)
12	Total number of low volume intersections per mile
13	Number of lanes on by-pass
14	Degree of curvature, degrees
15	Percent no-passing zone
16	Percent change in grade, absolute value
17	Number of signalized intersections adjacent to section
18	Number of intersections adjacent to section
19	Geometric modulus
20	Practical capacity, vehicles per hour
21	ADT, vehicles per day
22	Width of driveways per mile (side toward urban area), feet
23	Width of driveways per mile (side opposite urban area), feet
24	Operating speed, mph
25	Total width of driveways per mile, feet
26	Distance from extremities of by-pass, feet
27	Number of sections from extremities of by-pass
28	Length of turning lanes in section, feet
56	ADT per practical capacity

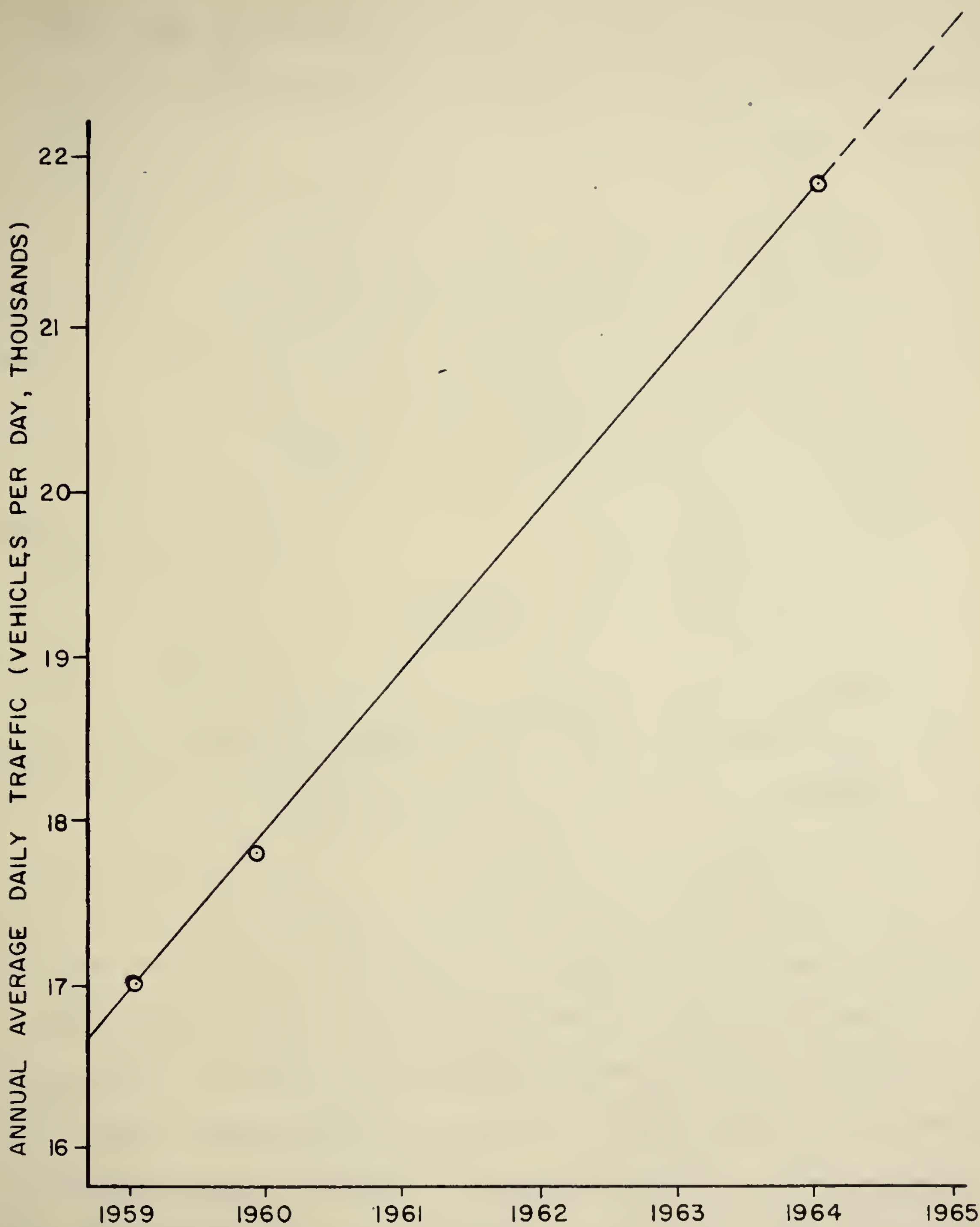

FIGURE 11 ANNUAL AVERAGE DAILY TRAFFIC ON U.S. 52 BY-PASS SOUTH OF S.R. 26.

traffic volume for each study section. Therefore, by knowing the location, year, month, day, and hour of an accident, the hourly volume was estimated by applying the appropriate factors to volume counts taken on or near each section during this study.

Appendix B shows the 1963 annual average daily traffic volumes for each leg of every intersection. Also shown on each figure in Appendix B are percentages of the approach volumes that make the indicated turning movements. The percentages are averages for several daylight periods.

Figure 12 is an illustration of the 1963 ADT volume on the by-pass and the cross streets.

Capacity

The practical capacity for each nonintersection study section was calculated by the method described in the Highway Capacity Manual (5).

In order to determine the practical capacities of the signalized intersections a study was made to determine the effectiveness of paved shoulders in increasing the practical capacity. Possible capacities were obtained for each approach to the intersection by counting the number of vehicles entering from that approach per loaded cycle. A loaded cycle was one that always had one or more vehicles waiting to proceed through the intersection. These counts were then converted to a volume per hour of green time. The counts were then adjusted by appropriate factors from the Highway Capacity Manual for practical capacity, left and right turns, commercial vehicles, parking, and bus stops. This study indicated that each paved shoulder of the by-pass was carrying approximately one-third the capacity of a properly constructed and signed turning lane (see Figures 13 and 14).

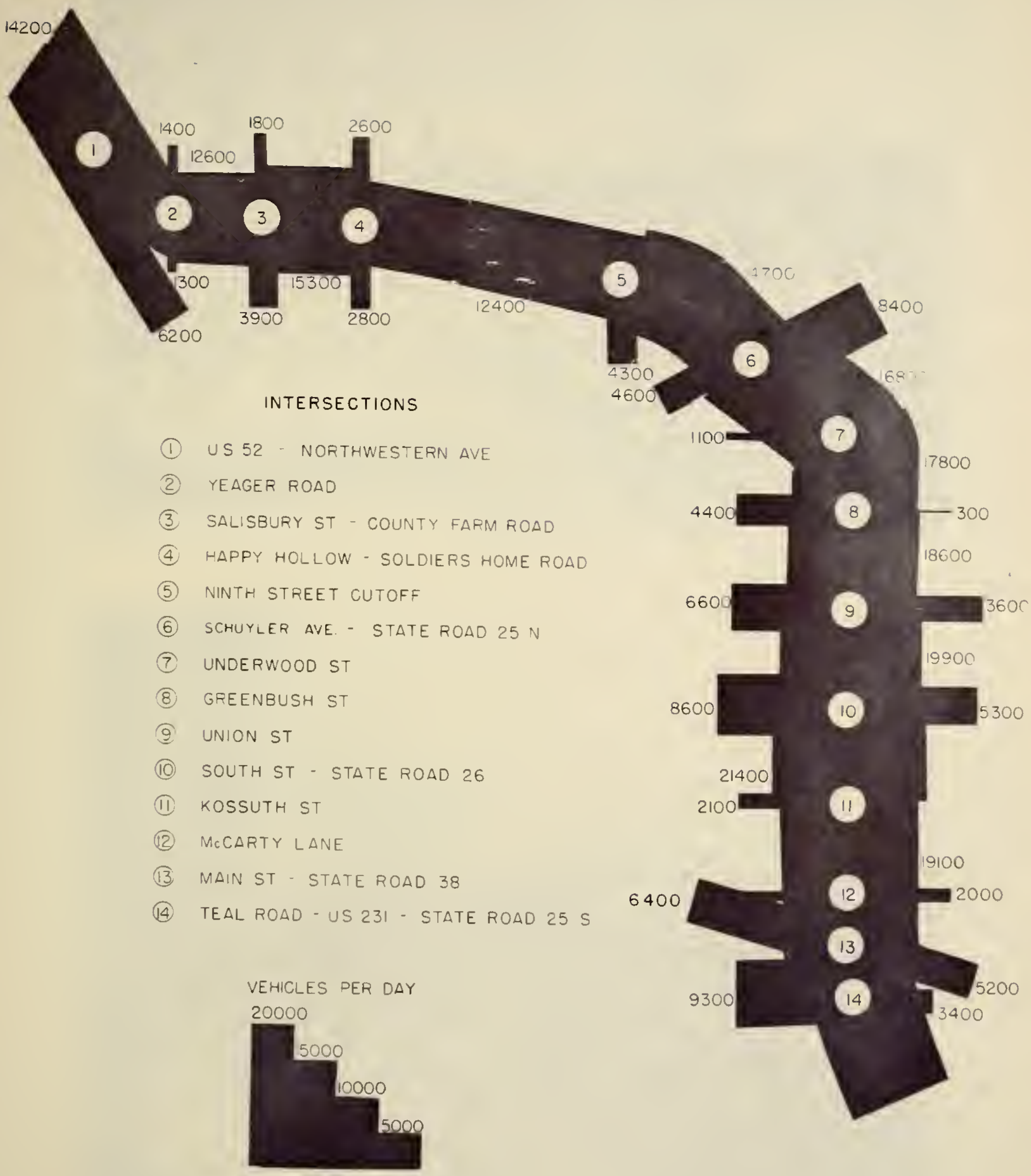

FIGURE 12 1963 ADT VOLUME ON THE U.S. 52 BY-PASS AND CROSS STREETS.

FIGURE 13 MANEUVERING ON PAVED SHOULDER AROUND LEFT TURN VEHICLE.

FIGURE 14 PAVED SHOULDER AVAILABLE FOR USE OF THROUGH VEHICLES.

The practical capacity for each signalized intersection was computed using the revised curves for the Highway Capacity Manual (10) for one eleven foot through lane in each direction. Then the practical capacity was calculated for an extra turning lane if more than one lane existed for a direction of travel. This lane was assumed to be a left turn only lane if the predominant turning movement at that approach was left and assumed to be a right turn only lane if the predominant turning movement at that approach was right. If the additional lane was only a paved shoulder not constructed, signed, or used exclusively as a turning lane, only one-third of the turning lane capacity was added to the through lane capacity. The practical capacities were thus determined for the conditions that existed at each signalized intersection.

The possible capacity for non-signalized intersections was calculated in the following manner. The headway distribution on the by-pass was assumed to be very similar to that shown on page 40 of the Highway Capacity Manual. The average acceptable gap at stop-controlled intersections was considered as eight seconds (18). Each succeeding vehicle was assumed to require an additional four seconds to move to the next position in the queue and stop (13). Based on these assumptions, for any given hourly volume on the major street, an approach capacity was determined for the minor street. An example calculation is shown in Table 3. The relationship between hourly volume in the major direction on the major street and hourly capacity on the minor street approach is shown in Figure 15.

TABLE 3

COMPUTATION OF POSSIBLE CAPACITY FOR A TWO-WAY STOP CONTROLLED INTERSECTION

Headway Group (secs.)	Percentage of Total Headways in this Group	Major Street Hourly Volume in one direction	Average Length of Gap (sec.)	Time in these Headways (sec.)	Total Gaps	Number of Vehicles
% ≤ 8	63	300	2.6	492	189	0
8 < % ≤ 12	6	300	10.0	180	18	18
12 < % ≤ 16	6	300	14.0	252	18	36
16 < % ≤ 20	5	300	18.0	270	15	45
20 < % ≤ 24	3	300	22.0	198	9	36
				1392	249	135

Headway Group (sec.)	No. of Vehicles entering from minor street
< 8	0
8 - 12	1
12 - 16	2
16 - 20	3
20 - 24	4
24 - 28	5
28 - 32	6
32 - 36	7
36 - 40	8
40 - 44	9
44 - 48	10

Number of seconds in headways > 24 sec. = 3600 - 1392 = 2208

Number of gaps > 24 secs. = 300 - 249 = 51

Average length of headways > 24 sec. = $\frac{2208}{51}$ = 43.3 = 44 secs.

Number of vehicles entering from minor streets in gap of 44 sec. = 9

Number of vehicles using gaps > 24 sec. = 9 x 51 = 459

Minor street capacity = 135 + 459 = 594 vehicles per hour

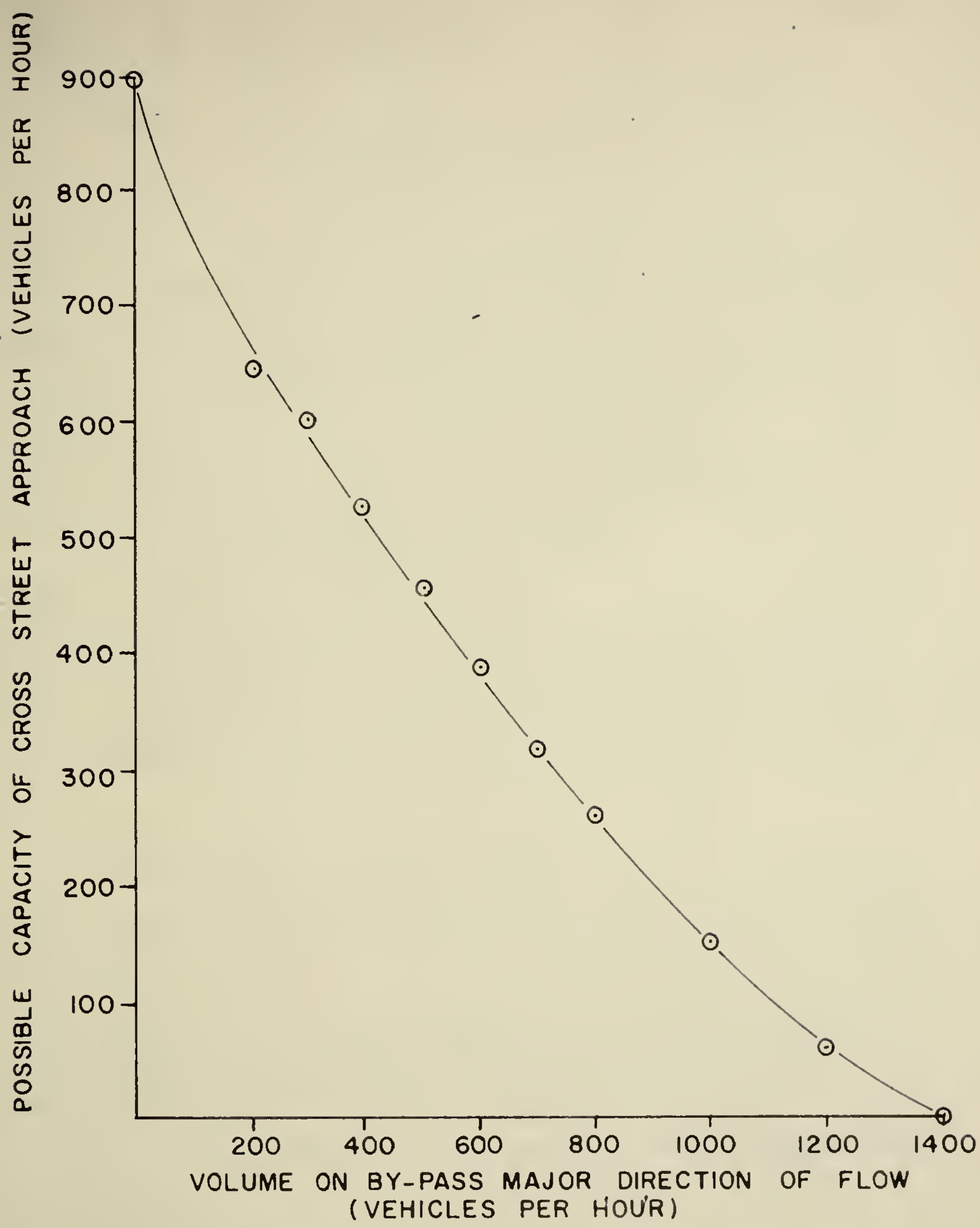

FIGURE 15 POSSIBLE CAPACITY OF A STOP-CONTROLLED CROSS STREET APPROACH FOR MAJOR DIRECTION HOURLY VOLUMES ON THE BY-PASS.

ANALYSES OF DATA

The data for the many variables were analyzed by multiple linear regression and the technique of quality control was applied to each section. Accident rates were also calculated for each section and collision-condition diagrams were prepared for each accident.

Multiple Linear Regression

This method was utilized to provide a generalized analysis of the causes of accidents at intersections and sections of a high-volume highway and to provide an expression for predicting accidents at each such location.

The variables used are shown in Tables 1 and 2. Twenty-nine prediction equations were developed for intersections and 27 for non-intersections.

The computer program used in this study for the multiple linear regression analysis was the BIMD 2R, "Stepwise Regression" (19). The program deck was available through the Purdue Statistical Laboratory Library Program.

This program computed a sequence of multiple linear regression equations in a stepwise manner. At each step one variable was added to the regression equation. The variable added was the one which made the greatest reduction in the error sum of squares. Equivalently it was the variable which had the highest partial correlation with the dependent variable partialed on the variables which had already been added; and equivalently it was the variable which, if it were to be added would have the highest F value. In addition, variables were automatically removed when their F values became too low. This technique is sometimes called the "building up" method.

Intersections.

All of the variables listed in Table 1 were used in the preliminary analysis. These results were examined and certain variables were deleted. Some of the deleted variables had very small simple correlations with the dependent variable. Variables numbered 14 and 25 had an intercorrelation coefficient of 0.917. In such cases one of the variables, in this case variable number 14, was deleted from further calculations.

Table 4 contains the variables that were used in the final analysis. This table should be used for reference in the following discussion.

Prediction equations can be obtained for each of the dependent variables in Table 5. These equations are obtained from Table 6 for each of the dependent variables as shown in the following example for Y_{28}, total accident rate at intersections.

$$Y_{28} = -309.860 - 0.908X_2 + 0.014X_3 + 0.025X_4 + 4.868X_{11} + 4.832X_{13} + 10.585X_{15} - 0.154X_{21}$$

The multiple correlation coefficient equals 0.873. The variables in this example explain approximately 76 percent (r^2) of the variation in intersection accident rates.

TABLE 4

INDEPENDENT VARIABLES USED IN FINAL MULTIPLE LINEAR REGRESSION ANALYSIS

Intersections

Variable Number	Description
2	Percent green time on by-pass, percent
3	By-pass ADT, vehicles per day
4	Cross street ADT, vehicles per day
5	Total ADT, vehicles per day
11	Maximum percent left turns from a by-pass approach, percent
12	Maximum percent left turns from a cross street approach, percent
13	Maximum approach speed, mph
15	Total number of establishments within 200 feet of intersection
16	Total number of driveways within 200 feet of intersection
19	Number of approaches to intersection
21	Total width of driveways, feet
22	Maximum percent right turns from by-pass, percent
23	Maximum percent right turns from cross street, percent
25	Distance from extremities of by-pass, feet

TABLE 5

DEPENDENT VARIABLES - INTERSECTIONS

28	Total accident rate (Accidents per 100 million vehicles)
29	Accident cost (Dollars lost in injuries and property damage)
30	Injury accidents (Injury accident per 100 MV)
31	Right turn accidents (Accidents per 100 MV)
32	Left turn accidents (Accidents per 100 MV)
33	Type I accidents (Accidents per 100 MV)
34	Type II accidents (Accidents per 100 MV)
35	Property damage only accidents (Accidents per 100 MV)
36	Day accidents (Accidents per 100 MV)
37	Night accidents (Accidents per 100 MV)
38	Weekend accidents (Accidents per 100 MV)
39	Weekday accidents (Accidents per 100 MV)
40	Accidents with hourly volumes less than 600 vph (Accidents per 100 MV)
41	Accidents with hourly volumes between 600 - 800 vph (Accidents per 100 MV)
42	Accidents with hourly volumes between 800 - 1000 vph (Accidents per 100 MV)
43	Accidents with hourly volumes between 1000 - 1200 vph (Accidents per 100 MV)
44	Accidents with hourly volumes between 1200 - 1400 vph (Accidents per 100 MV)
45	Accidents with hourly volumes between 1400 - 1600 vph (Accidents per 100 MV)
46	Accidents with hourly volumes between 1600 - 1800 vph (Accidents per 100 MV)
47	Accidents with hourly volumes greater than 1800 vph (Accidents per 100 MV)
48	Tippecanoe county vehicle accidents (Vehicles in accidents per 100 MV)
49	Non-Tippecanoe county vehicle accidents (Vehicles in accidents per 100 MV)
50	Northwest bound vehicle accidents (Vehicles in accidents per 100 MV)
51	Southeast bound vehicle accidents (Vehicles in accidents per 100 MV)
52	Clear weather accidents (Accidents per 100 MV)
53	Rainy or snowy weather accidents (Accidents per 100 MV)
54	Passenger car accidents (Vehicles in accidents per 100 MV)
55	Truck accidents (Vehicles in accidents per 100 MV)
56	Arrests (Arrests of drivers in accidents per 100 MV)

TABLE 6

COEFFICIENTS FOR MULTIPLE LINEAR REGRESSION EQUATIONS

- INTERSECTIONS

	Dependent Variables				
	28	29	30	31	32
Constant	-309.860	23467.000	-348.630	-3.936	-301.220
INDEPENDENT VARIABLES					
X_2	- 0.908	- 102.330	- 0.238	0.202	
X_3	0.014		0.009	-0.001	
X_4	0.025 *			0.006	
X_5		1.286			0.010
X_{11}	4.868		5.398		8.175
X_{12}			1.250		2.378
X_{13}	4.832	488.930	2.433		2.940
X_{15}	10.585		10.456	1.499	9.167
X_{16}			- 2.542		
X_{19}					- 70.827
X_{21}	- 0.154	- 10.770			
X_{22}		- 18.790		0.559	
X_{23}		- 26.720	0.493		1.408
X_{25}					
r	0.873	0.822	0.742	0.667	0.809

* The coefficient underlined represents the variable that is the most significant in the regression equation.

TABLE 6 (Continued)

	Dependent Variables				
	33	34	35	36	37
Constant	-390.530	13.353	-29.230	-1367.000	-198.082
INDEPENDENT VARIABLES					
X_2	- 0.978			5.855	0.993
X_3		-0.009		0.023	
X_4	- 0.005		0.034	0.143	0.061
X_5	0.014	0.009	0.004		
X_{11}	5.940				
X_{12}					
X_{13}	6.644	-1.027			
X_{15}		11.666	8.716		
X_{16}				- 17.030	
X_{19}				170.080	
X_{21}		-0.088	- 0.166		
X_{22}				- 11.950	
X_{23}					2.952
X_{25}					- 0.005
r	0.861	0.843	0.859	0.555	0.568

TABLE 6 (Continued)

		Dependent Variables				
		38	39	40	41	42
	Constant	-1108.930	-1471.600	132.170	-409.880	-416.160
INDEPENDENT VARIABLES	X_2		3.061	- 0.598	2.350	1.944
	X_3	0.037		0.002		
	X_4	0.016	0.042	0.009		
	X_5		0.034		0.011	0.007
	X_{11}	15.249	12.040		11.269	10.880
	X_{12}					
	X_{13}	6.539	11.143			3.151
	X_{15}					
	X_{16}			7.698		
	X_{19}	60.489		-29.430		
	X_{21}			- 0.199		
	X_{22}		- 6.446			
	X_{23}		2.486			
	X_{25}			0.001		0.006
	r	0.723	0.602	0.593	0.468	0.482

TABLE 6 (Continued)

	Dependent Variables				
	43	44	45	46	47
Constant	-2618.170	11356.980	12895.600	10331.700	-8576.900
INDEPENDENT VARIABLES					
X_2	10.310	- 105.990	- 152.000	17.499	32.130
X_3		1.925			- 0.748
X_4			- 2.369	0.645	
X_5	0.036	- 1.817		0.244	0.984
X_{11}	46.289				
X_{12}					
X_{13}		576.180	760.080	77.740	
X_{15}		-2251.000	-2996.400		
X_{16}		824.500	1182.900		
X_{19}	223.440				
X_{21}		17.899	26.122		
X_{22}		- 182.450	- 250.900	- 59.290	
X_{23}				24.310	23.140
X_{25}				- 0.062	- 0.097
r	0.553	0.527	0.487	0.805	0.750

TABLE 6 (Continued)

	Dependent Variables				
	48	49	50	51	52
Constant	-5772.800	-621.010	6.398	-1088.600	-231.041
INDEPENDENT VARIABLES					
X_2	- 17.001	- 2.959			- 0.652
X_3	0.217	0.029	0.019	0.063	0.012
X_4		<u>0.024</u>	<u>0.072</u>		<u>0.022</u>
X_5				- <u>0.026</u>	
X_{11}	<u>79.210</u>	7.747		31.270	4.201
X_{12}					
X_{13}	56.400	12.250	-10.784		2.989
X_{15}			28.656		9.438
X_{16}				47.928	
X_{19}			161.810		
X_{21}			- 1.259	- 0.758	- 0.217
X_{22}				18.175	
X_{23}	28.011		- 4.230	2.645	
X_{25}	- 0.051		0.018		
r	0.655	0.850	0.792	0.821	0.854

TABLE 6 (Continued)

		Dependent Variables			
		53	54	55	56
	Constant	1939.700	-279.620	753.340	-191.270
INDEPENDENT VARIABLES	X_2		- 2.223	- 4.113	
	X_3		0.022		0.007
	X_4	0.116	0.076	0.030	0.012
	X_5				
	X_{11}				2.647
	X_{12}			- 3.783	
	X_{13}	16.175	6.527		3.637
	X_{15}	-840.280	23.470		
	X_{16}	434.330			
	X_{19}				- 15.306
	X_{21}		- 0.438	- 0.316	
	X_{22}				
	X_{23}	- 38.940			
	X_{25}	0.158			
	r	0.743	0.860	0.639	0.813

A summary table from the computer program illustrated the increase in the multiple correlation coefficient squared, r^2, after each variable was added to the regression equation. Only variables which contributed approximately 0.02 or more to the cumulative r^2 were considered sufficiently significant to be retained in the regression equation.

Important variables in estimating the accident rate at intersections (see example above) are the percentage of green time allotted to the by-pass (100 percent green time means there was no traffic signal present) (X_2), the by-pass daily traffic (X_3), the cross-street daily volume (X_4), the percent of left turns from the by-pass (X_{11}), the maximum approach speed to the intersection (X_{13}), the number of establishments within 200 feet of the intersection (X_{15}), and the total width of driveways (X_{21}).

The simple correlation coefficients between each variable and all other variables are shown in Table 7 . For the independent variables in the above example these simple correlation coefficients with the dependent variable, accidents per 100 million vehicles (Y_{28}), are as follows.

Independent Variable	Simple Correlation Coefficients
X_2	-0.598
X_3	0.280
X_4	0.766
X_{11}	0.493
X_{13}	0.256
X_{15}	0.032
X_{21}	0.207

The means and standard deviations of each of the variables are shown in Table 8 .

TABLE 7

SIMPLE CORRELATION COEFFICIENTS FOR EACH VARIABLE AND ALL OTHER VARIABLES-INTERSECTIONS

CORRELATION MATRIX

VARIABLE NUMBER	1	2	3	4	5	6	7	8	9	10
1	1.000	-0.873	0.375	0.659	0.620	-0.176	-0.067	0.012	0.538	0.231
2		1.000	-0.185	-0.651	-0.481	-0.002	-0.102	-0.331	-0.606	-0.363
3			1.000	0.272	0.856	0.145	0.039	-0.178	0.065	-0.427
4				1.000	0.730	0.176	-0.077	0.156	0.484	0.073
5					1.000	0.198	-0.013	-0.043	0.306	-0.264
6						1.000	0.149	0.317	0.164	-0.084
7							1.000	0.604	0.197	-0.019
8								1.000	0.185	0.230
9									1.000	0.402
10										1.000

VARIABLE NUMBER	11	12	13	14	15	16	17	18	19	20
1	0.272	-0.312	-0.162	0.417	0.495	0.535	0.063	-0.300	0.555	-0.117
2	-0.420	0.176	0.073	-0.201	-0.287	-0.311	0.062	-0.106	-0.387	0.087
3	-0.239	-0.447	-0.465	0.323	0.548	0.418	-0.114	-0.367	0.114	0.317
4	0.580	-0.352	0.069	-0.012	0.121	0.252	-0.174	-0.164	0.405	0.162
5	0.141	-0.507	-0.293	0.223	0.454	0.432	-0.174	-0.349	0.298	0.312
6	0.145	0.183	0.094	-0.619	-0.024	-0.037	-0.385	0.189	0.002	0.723
7	0.040	0.266	0.322	-0.226	-0.442	-0.476	-0.056	0.161	-0.480	0.103
8	0.230	0.327	0.313	-0.457	-0.337	-0.338	-0.206	0.373	-0.172	0.188
9	0.545	-0.280	0.115	0.086	-0.003	0.051	-0.123	-0.027	0.312	0.398
10	0.412	0.135	0.207	-0.068	-0.016	0.131	-0.139	0.230	0.082	-0.396
11	1.000	-0.416	0.058	-0.116	-0.294	-0.129	0.046	0.240	0.130	-0.095
12		1.000	0.529	-0.478	-0.370	-0.363	-0.227	0.039	-0.067	0.087
13			1.000	-0.333	-0.513	-0.456	-0.059	0.061	-0.142	0.232
14				1.000	0.521	0.290	0.475	-0.130	0.076	-0.498
15					1.000	0.896	0.027	-0.203	0.368	-0.022
16						1.000	-0.102	-0.309	0.532	-0.031
17							1.000	0.125	-0.070	-0.285
18								1.000	-0.494	-0.135
19									1.000	0.141
20										1.000

TABLE 7 (CONTINUED)

VARIABLE NUMBER	21	22	23	24	25	26	27	28	29	30
1	0.629	0.420	-0.344	0.519	0.356	0.579	0.520	0.585	0.430	0.377
2	-0.462	-0.382	0.480	-0.526	-0.224	-0.519	-0.539	-0.598	-0.468	-0.465
3	0.463	0.112	-0.129	0.285	0.076	0.176	0.281	0.280	0.242	0.114
4	0.510	0.546	-0.597	0.662	0.070	0.265	0.473	0.766	0.576	0.427
5	0.602	0.373	-0.412	0.557	0.092	0.267	0.454	0.610	0.481	0.310
6	0.014	0.044	-0.460	0.383	-0.616	-0.319	-0.050	0.175	0.260	0.242
7	-0.540	0.256	-0.187	0.259	-0.201	-0.103	0.246	0.214	0.369	0.358
8	-0.374	0.085	-0.401	0.343	-0.380	-0.154	0.199	0.306	0.451	0.469
9	0.299	0.251	-0.267	0.526	0.175	0.487	0.856	0.475	0.355	0.393
10	0.083	-0.082	-0.360	-0.026	-0.001	0.467	0.174	0.045	0.025	0.208
11	0.061	-0.030	-0.337	0.245	0.025	0.046	0.446	0.493	0.260	0.342
12	-0.486	0.301	-0.225	0.023	-0.419	-0.166	-0.473	-0.220	0.073	0.074
13	-0.500	0.513	-0.380	0.289	-0.141	-0.264	-0.042	0.255	0.422	0.345
14	0.329	0.062	0.227	-0.171	0.917	0.394	0.227	0.042	-0.082	-0.068
15	0.777	-0.068	0.018	0.055	0.319	0.405	0.030	0.032	-0.044	-0.054
16	0.847	-0.081	0.016	0.120	0.106	0.484	0.050	0.085	-0.055	-0.065
17	-0.186	-0.100	0.254	-0.233	0.434	-0.211	-0.061	-0.145	-0.258	-0.261
18	-0.313	-0.259	-0.078	-0.208	-0.013	-0.216	-0.088	-0.090	-0.066	0.064
19	0.583	0.129	-0.082	0.394	-0.020	0.357	0.248	0.252	0.112	0.093
20	0.010	0.145	-0.227	0.360	-0.504	-0.383	0.008	0.225	0.336	0.216
21	1.000	0.119	-0.127	0.196	0.259	0.663	0.259	0.207	-0.005	-0.025
22		1.000	-0.576	0.536	0.203	0.238	0.118	0.538	0.571	0.384
23			1.000	-0.514	0.181	-0.130	-0.106	-0.570	-0.605	-0.549
24				1.000	-0.196	0.078	0.531	0.640	0.599	0.446
25					1.000	0.401	0.210	0.079	-0.057	-0.036
26						1.000	0.417	0.085	-0.044	0.031
27							1.000	0.462	0.342	0.326
28								1.000	0.881	0.800
29									1.000	0.917
30										1.000

TABLE 7 (CONTINUED)

VARIABLE NUMBER	31	32	33	34	35	36	37	38	39	40
1	0.307	-0.115	0.506	0.621	0.619	0.034	0.146	0.404	0.041	0.366
2	-0.276	-0.088	-0.575	-0.442	-0.599	-0.031	-0.122	-0.354	-0.055	-0.336
3	0.017	-0.133	0.180	0.572	0.324	0.172	0.177	0.337	0.185	0.209
4	0.578	0.278	0.729	0.437	0.820	0.372	0.429	0.633	0.406	0.249
5	0.322	0.055	0.519	0.641	0.670	0.322	0.356	0.579	0.349	0.282
6	0.024	0.386	0.246	-0.104	0.110	0.303	0.188	0.311	0.298	-0.046
7	0.050	0.354	0.308	-0.261	0.122	-0.066	0.040	0.051	-0.010	0.134
8	0.235	0.284	0.374	-0.166	0.213	0.032	0.080	0.080	0.099	0.114
9	0.135	0.117	0.560	-0.082	0.464	0.341	0.267	0.485	0.342	0.080
10	0.012	-0.005	0.084	-0.091	-0.019	-0.119	-0.165	-0.059	-0.105	0.072
11	0.257	0.359	0.527	-0.016	0.511	0.329	0.311	0.457	0.368	0.156
12	-0.036	0.121	-0.159	-0.315	-0.341	-0.335	-0.309	-0.371	-0.362	-0.221
13	0.198	0.462	0.346	-0.403	0.160	-0.021	-0.046	0.027	0.015	-0.015
14	0.025	-0.316	-0.090	0.478	0.098	-0.157	-0.126	-0.022	-0.155	0.205
15	0.024	-0.371	-0.098	0.677	0.078	-0.034	-0.024	0.088	-0.051	0.216
16	0.093	-0.364	-0.024	0.605	0.153	0.041	0.094	0.148	0.028	0.205
17	-0.099	-0.159	-0.186	0.003	-0.076	-0.138	-0.116	-0.101	-0.144	0.120
18	-0.153	0.359	-0.029	-0.232	-0.142	-0.049	-0.080	-0.145	-0.017	0.047
19	0.188	-0.392	0.187	0.339	0.307	0.205	0.172	0.290	0.161	-0.075
20	-0.025	0.238	0.286	-0.135	0.187	0.410	0.264	0.362	0.410	-0.146
21	0.219	-0.316	0.126	0.556	0.295	0.193	0.178	0.303	0.167	0.095
22	0.514	0.316	0.538	0.191	0.514	-0.003	0.100	0.265	0.017	0.137
23	-0.393	-0.395	-0.569	-0.251	-0.497	-0.073	-0.037	-0.353	-0.113	-0.199
24	0.430	0.178	0.650	0.222	0.645	0.299	0.332	0.527	0.317	0.311
25	0.162	-0.170	-0.012	0.304	0.128	-0.137	-0.111	-0.038	-0.127	0.142
26	0.194	-0.364	0.062	0.242	0.116	-0.059	-0.046	0.035	-0.070	0.015
27	0.086	0.017	0.511	0.030	0.482	0.372	0.325	0.501	0.380	0.119
28	0.486	0.493	0.968	0.384	0.966	0.310	0.431	0.714	0.371	0.460
29	0.325	0.544	0.863	0.310	0.753	0.298	0.369	0.647	0.348	0.355
30	0.267	0.501	0.790	0.255	0.624	0.291	0.314	0.616	0.327	0.313
31	1.000	0.121	0.430	0.253	0.527	0.001	0.149	0.182	0.056	0.233
32		1.000	0.544	-0.086	0.400	0.205	0.304	0.344	0.249	0.152
33			1.000	0.174	0.923	0.336	0.439	0.718	0.390	0.425
34				1.000	0.408	-0.018	0.093	0.252	-0.000	0.240
35					1.000	0.284	0.434	0.670	0.351	0.467
36						1.000	0.821	0.795	0.983	-0.062
37							1.000	0.782	0.849	0.155
38								1.000	0.787	0.266
39									1.000	-0.011
40										1.000

TABLE 7 (CONTINUED)

VARIABLE NUMBER	41	42	43	44	45	46	47	48	49	50
1	-0.058	-0.018	-0.062	0.178	0.205	0.190	0.177	0.314	0.599	0.427
2	0.060	0.007	0.047	-0.114	-0.145	-0.146	-0.124	-0.335	-0.541	-0.438
3	0.078	-0.040	0.042	-0.191	-0.124	0.358	0.398	0.260	0.259	0.260
4	0.196	0.175	0.264	-0.031	0.014	0.598	0.574	0.358	0.735	0.470
5	0.160	0.065	0.171	-0.152	-0.081	0.575	0.591	0.377	0.579	0.437
6	0.249	-0.019	0.242	-0.138	-0.078	0.349	0.315	0.135	0.166	-0.107
7	0.051	0.075	-0.120	-0.141	-0.116	-0.084	-0.033	-0.039	0.182	0.195
8	0.005	0.020	-0.038	-0.062	-0.049	0.086	0.103	0.005	0.345	0.317
9	0.261	0.365	0.365	-0.089	-0.064	0.339	0.191	0.325	0.478	0.174
10	-0.069	0.122	0.058	0.276	0.218	-0.151	-0.228	-0.145	0.116	-0.024
11	0.332	0.351	0.388	0.048	0.043	0.325	0.253	0.320	0.444	0.272
12	-0.315	-0.218	-0.309	0.061	0.014	-0.417	-0.352	-0.361	-0.153	-0.130
13	-0.018	0.124	0.028	0.153	0.096	-0.031	-0.043	-0.042	0.269	0.084
14	-0.033	0.094	-0.126	-0.081	-0.093	-0.215	-0.164	-0.117	0.030	0.272
15	-0.069	-0.156	-0.110	0.064	0.112	0.074	0.100	-0.035	0.057	-0.014
16	-0.055	-0.156	-0.019	0.201	0.239	0.194	0.185	0.022	0.089	-0.123
17	0.078	-0.153	-0.133	-0.029	-0.050	-0.212	-0.158	-0.118	-0.177	0.089
18	0.102	-0.097	-0.000	-0.091	-0.084	-0.145	-0.135	-0.101	-0.054	-0.026
19	-0.080	0.027	0.167	0.150	0.137	0.269	0.214	0.161	0.275	0.087
20	0.272	0.001	0.281	-0.078	-0.024	0.502	0.435	0.400	0.225	-0.070
21	0.070	-0.014	0.133	0.119	0.173	0.325	0.267	0.166	0.217	-0.021
22	-0.003	0.026	-0.083	-0.053	-0.043	0.097	0.142	-0.018	0.518	0.379
23	-0.043	-0.045	-0.065	-0.076	-0.074	-0.202	-0.225	-0.051	-0.601	-0.430
24	0.015	0.101	0.191	-0.092	-0.051	0.437	0.422	0.273	0.606	0.370
25	0.037	0.172	-0.088	-0.078	-0.091	-0.227	-0.202	-0.107	0.065	0.255
26	-0.059	0.076	0.009	0.116	0.119	-0.045	-0.111	-0.080	0.123	-0.003
27	0.191	0.364	0.343	-0.130	-0.094	0.418	0.305	0.358	0.458	0.287
28	0.246	0.335	0.226	-0.038	-0.026	0.431	0.426	0.371	0.964	0.733
29	0.272	0.274	0.168	0.029	0.049	0.397	0.439	0.228	0.888	0.677
30	0.330	0.354	0.201	0.153	0.161	0.285	0.322	0.163	0.835	0.618
31	0.032	0.073	-0.009	-0.122	-0.129	0.118	0.205	0.004	0.427	0.322
32	0.275	0.245	0.188	-0.029	-0.008	0.185	0.220	0.133	0.470	0.251
33	0.288	0.360	0.253	-0.053	-0.037	0.431	0.406	0.420	0.928	0.647
34	-0.115	-0.102	-0.134	0.068	0.102	0.179	0.252	-0.013	0.402	0.436
35	0.178	0.292	0.213	-0.112	-0.099	0.445	0.417	0.419	0.906	0.707
36	0.738	0.547	0.919	0.000	0.077	0.870	0.790	0.126	0.266	0.177
37	0.622	0.541	0.736	0.014	0.089	0.783	0.711	0.038	0.337	0.291
38	0.625	0.494	0.680	0.063	0.133	0.781	0.737	0.255	0.668	0.479
39	0.738	0.578	0.921	-0.018	0.052	0.884	0.794	0.128	0.317	0.236
40	0.128	-0.051	-0.113	0.070	0.071	-0.019	0.139	0.078	0.390	0.450
41	1.000	0.355	0.659	-0.038	0.022	0.579	0.627	0.047	0.169	0.089
42		1.000	0.636	-0.148	-0.145	0.358	0.246	0.062	0.304	0.282
43			1.000	-0.002	0.041	0.728	0.600	0.047	0.170	0.114
44				1.000	0.986	-0.045	-0.051	-0.065	0.016	-0.092
45					1.000	0.036	0.035	-0.049	0.022	-0.105
46						1.000	0.902	0.232	0.399	0.223
47							1.000	0.157	0.395	0.283
48								1.000	0.376	0.043
49									1.000	0.730
50										1.000

TABLE 7 (CONTINUED)

VARIABLE NUMBER	51	52	53	54	55	56
1	0.645	0.457	0.533	0.609	0.435	0.387
2	-0.494	-0.519	-0.451	-0.503	-0.520	-0.461
3	0.367	0.239	0.141	0.329	0.207	0.152
4	0.560	0.690	0.572	0.758	0.502	0.673
5	0.561	0.540	0.407	0.641	0.417	0.470
6	-0.015	0.294	-0.182	0.189	-0.043	0.276
7	0.018	0.298	-0.162	0.182	0.195	0.222
8	-0.058	0.428	-0.107	0.269	0.206	0.304
9	0.346	0.477	0.192	0.434	0.322	0.407
10	0.070	-0.052	0.279	0.001	0.056	0.097
11	0.245	0.502	0.304	0.433	0.400	0.465
12	-0.252	-0.183	-0.193	-0.201	-0.335	-0.136
13	0.066	0.283	0.092	0.225	-0.022	0.393
14	0.255	-0.049	0.206	0.061	0.168	-0.102
15	0.350	-0.088	0.252	0.085	0.087	-0.073
16	0.446	-0.083	0.387	0.121	0.109	-0.020
17	-0.124	-0.070	-0.199	-0.149	0.015	-0.109
18	-0.296	-0.003	-0.151	-0.115	0.172	0.106
19	0.397	0.168	0.314	0.269	0.095	0.051
20	0.086	0.336	-0.178	0.246	-0.009	0.307
21	0.416	0.047	0.434	0.232	0.183	0.102
22	0.422	0.467	0.384	0.556	0.216	0.526
23	-0.315	-0.525	-0.405	-0.577	-0.220	-0.602
24	0.449	0.643	0.271	0.655	0.307	0.513
25	0.193	-0.001	0.220	0.374	0.212	-0.005
26	0.287	-0.097	0.383	0.068	0.166	-0.021
27	0.306	0.475	0.152	0.425	0.343	0.310
28	0.789	0.942	0.647	0.979	0.643	0.883
29	0.683	0.868	0.480	0.884	0.468	0.930
30	0.652	0.788	0.476	0.790	0.482	0.792
31	0.425	0.443	0.391	0.427	0.385	0.416
32	0.217	0.558	0.159	0.473	0.230	0.631
33	0.708	0.934	0.561	0.935	0.616	0.871
34	0.519	0.250	0.527	0.461	0.275	0.240
35	0.759	0.894	0.651	0.943	0.646	0.815
36	0.172	0.404	-0.011	0.318	0.110	0.396
37	0.289	0.509	0.073	0.431	0.207	0.461
38	0.566	0.754	0.300	0.717	0.371	0.678
39	0.200	0.459	0.027	0.373	0.163	0.464
40	0.447	0.441	0.280	0.442	0.393	0.366
41	0.231	0.340	-0.031	0.236	0.160	0.390
42	0.168	0.350	0.161	0.270	0.296	0.332
43	0.117	0.308	-0.033	0.203	0.047	0.328
44	0.046	-0.083	0.119	-0.022	-0.185	0.017
45	0.054	-0.057	0.090	-0.001	-0.170	0.032
46	0.262	0.479	0.139	0.446	0.212	0.492
47	0.320	0.481	0.155	0.430	0.324	0.459
48	0.265	0.339	0.222	0.354	0.365	0.291
49	0.739	0.896	0.671	0.947	0.637	0.878
50	0.430	0.719	0.461	0.734	0.481	0.599
51	1.000	0.650	0.690	0.785	0.559	0.648
52		1.000	0.374	0.914	0.562	0.855
53			1.000	0.648	0.541	0.570
54				1.000	0.543	0.859
55					1.000	0.564
56						1.000

TABLE 8
VARIABLE MEANS AND STANDARD DEVIATIONS-INTERSECTIONS

VARIABLE	MEAN	STANDARD DEVIATION
1	0.38095	0.49151
2	79.83333	24.10740
3	15843.80945	2712.48019
4	3119.64285	2047.91287
5	18963.45215	3817.15594
6	1874.85713	1066.02895
7	0.35714	0.53289
8	0.11905	0.39524
9	484.28571	474.21894
10	273.57143	330.74615
11	12.78571	5.91623
12	45.71429	18.97532
13	42.92142	7.41184
14	4.00000	2.02424
15	3.42857	2.22122
16	7.00000	5.47723
17	0.61667	0.92319
18	0.65714	1.40819
19	3.66667	0.47712
20	2.35714	0.72655
21	282.14286	220.23618
22	12.14286	11.07969
23	43.57143	21.20877
24	69.50000	18.43810
25	7664.92853	5982.35895
26	1.38095	0.76357
27	2.04762	1.16770
28	177.90476	104.42451
29	9306.66663	7816.45068
30	41.35714	33.07996
31	15.90476	19.80984
32	60.00000	44.10021
33	148.57143	95.01762
34	18.80952	25.98896
35	135.38095	79.20826
36	273.33333	417.41512
37	157.14286	160.37753
38	222.61905	202.33212
39	200.00000	263.28987
40	50.21429	49.60307
41	127.11905	146.75700
42	189.50000	144.14816
43	304.73809	522.65006
44	1841.61903	7780.70319
45	2534.45236	12352.06165
46	906.47619	1794.98070
47	1058.50000	2350.44586
48	571.21428	990.98905
49	305.19048	202.65664
50	355.23809	243.92739
51	285.28571	249.52679
52	124.78571	84.42128
53	2672.35712	2064.44553
54	359.88095	219.48133
55	254.76190	228.49184
56	90.26190	55.38823

The independent variables most frequently appearing in the multiple linear regression equations for the several accident rates were percent green time on the by-pass (X_2), maximum approach speed (X_{13}), cross street ADT (X_4), and the by-pass ADT (X_3). At least one of the variables representing volume (either X_3, X_4, or X_5) was always significant in each of the intersection regression equations. The variable to appear significant the fewest times was the maximum percent left turns from a cross street approach (X_{12}).

Variables that were significant in predicting left-turn accidents but not right-turn accidents included total intersection ADT (X_5), maximum left turns from a by-pass approach (X_{11}), maximum percent left turns from a cross street approach (X_{12}) and maximum approach speed (X_{13}). Variables used in predicting right-turn accidents but not left-turn accidents were percent green time on by-pass (X_2), by-pass ADT (X_3), cross street ADT (X_4) and maximum percent right turns from the by-pass (X_{22}).

Total width of driveways (X_{21}) and total number of establishments (X_{15}) were significant for Type II* accidents while percent green time on the by-pass (X_2) and the maximum percent left turns from the by-pass were important in predicting Type I* accidents.

Maximum approach speed (X_{13}) was not a significant variable for property-damage-only accidents but commercial development was (X_{15} and X_{21}). Speed (X_{13}), left turns (X_{11} and X_{12}), and commercial development (X_{15} and X_{16}) were all significant for injury accidents.

Commercial development had no significant effect on the night accident rate, but the location of an intersection relative to the extremities of the by-pass did.

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* See page 126 for definition of Type I, II, III and IV accidents.

Weekend and weekday accident rates were affected by nearly the same variables. Percent green time on the by-pass, however, was significant in weekday but not weekend accidents.

The accidents occurring during hours of less than 1000 vehicles per hour appeared the most difficult to predict (multiple correlation coefficients of approximately 0.47). For volumes between 1000 and 1600 vehicles per hour, approach speed and commercial development were significant. Total volume and cross street volume were important variables for volumes greater than 1600 vehicles per hour.

Cross street volumes appeared to affect out-of-county drivers more than they affected Tippecanoe County drivers.

Approach speed was a more significant variable in predicting northwest bound vehicle accidents than southeast bound vehicle accidents.

Commercial development, approach speed and cross street traffic were significant for clear weather accidents as well as for accidents in inclement weather.

While left turns from the cross streets were significant in truck accidents, approach speed and number of establishments were important in passenger car accidents.

Approach speed was significant in accidents involving arrests.

The variable that was the most significant in each intersection multiple linear regression equation is underlined in Table 6 . The variable that is underlined most frequently is the cross street ADT (X_4).

Nonintersections

The variables listed in Table 9 are those remaining after other less significant variables were removed as in the intersection analysis.

TABLE 9

INDEPENDENT VARIABLES USED IN FINAL MULTIPLE LINEAR REGRESSION ANALYSIS

Nonintersections	
Variable Number	Description
3	Total number of establishments per mile
6	Total number of driveways per mile
9	Total shoulder width, feet
12	Total number of low volume intersections per mile
15	Percentage no-passing zones, percent
18	Number of intersections adjacent to section
19	Geometric modulus
20	Practical capacity, vehicles per hour
21	ADT, vehicles per day
24	Operating speed, mph
25	Total width of driveways per mile, feet
26	Distance from extremities of by-pass, feet
28	Length of turning lanes in section, feet
56	ADT per practical capacity

This table should be referred to when using the prediction equations. Table 10 is a listing of the dependent variables. The prediction equations can be determined from Table 11 by the same method previously illustrated for intersections. Independent variables that were significant in each of the dependent variable prediction equations are shown in this table. A variable was considered significant if it contributed approximately 0.02 to the cumulative r^2.

The variables used in the prediction equation for Y_{29}, accidents per 100 million vehicle miles, are total establishments per mile (X_3), the percent of no-passing zones (X_{15}), the number of intersections adjacent to the study section (X_{18}), the geometric modulus (X_{19}), the total width of driveways per mile (X_{25}) and the distance from the extremities of the by-pass (X_{26}). These variables had a multiple correlation coefficient of 0.574 and explained approximately 33 percent of the variation in nonintersection accident rates. This percentage is considerably less than that found for intersections.

The correlation coefficients of each variable with all other variables are shown in Table 12. The means and standard deviations of each variable are shown in Table 13.

The independent variables that were significant most often in the nonintersection multiple linear regression equations were the total number of establishments per mile (X_3), the length of turning lanes in the section (X_{28}), the total width of driveways per mile (X_{25}) and the geometric modulus (X_{19}). The independent variable that was significant the fewest times was the total shoulder width (X_9).

Independent variables significant in predicting total accident cost (Y_{30}) but not total accident rate (Y_{29}) were the total shoulder width (X_9),

TABLE 10

DEPENDENT VARIABLES - NONINTERSECTION

29 Total accident rate (Accidents per 100 million vehicle miles)

30 Accident cost (Dollars lost in injury and property damage)

31 Injury accidents (Injury accidents per 100 MVM)

32 Property damage only accidents (PDO accidents per 100 MVM)

33 Type II accidents (Accidents per 100 MVM)

34 Type III accidents (Accidents per 100 MVM)

35 Type IV accidents (Accidents per 100 MVM)

36 Northwest bound vehicle accidents (Vehicles in accidents per 100 MVM)

37 Southeast bound vehicle accidents (Vehicles in accidents per 100 MVM)

38 Accidents with hourly volumes less than 600 vph (Accidents per 100 MVM)

39 Accidents with hourly volumes between 600-800 vph (Accidents per 100 MVM)

40 Accidents with hourly volumes between 800-1000 vph (Accidents per 100 MVM)

41 Accidents with hourly volumes between 1000-1200 vph (Accidents per 100 MVM)

42 Accidents with hourly volumes between 1200-1400 vph (Accidents per 100 MVM)

43 Accidents with hourly volumes between 1400-1600 vph (Accidents per 100 MVM)

44 Accidents with hourly volumes between 1600-1800 vph (Accidents per 100 MVM)

45 Accidents with hourly volumes greater than 1800 vph (Accidents per 100 MVM)

46 Day accidents (Accidents per 100 MVM)

47 Night accidents (Accidents per 100 MVM)

48 Weekend accidents (Accidents per 100 MVM)

49 Weekday accidents (Accidents per 100 MVM)

50 Tippecanoe county vehicle accidents (Vehicles in accidents per 100 MVM)

51 Non-Tippecanoe county vehicle accidents (Vehicles in accidents per 100 MVM)

52 Clear weather accidents (Accidents per 100 MVM)

53 Rainy or snowy weather accidents (Accidents per 100 MVM)

54 Passenger car accidents (Vehicles in accidents per 100 MVM)

55 Truck accidents (Vehicles in accidents per 100 MVM)

TABLE 11

COEFFICIENTS FOR MULTIPLE LINEAR REGRESSION EQUATIONS

- NONINTERSECTIONS

	Dependent Variables				
	29	30	31	32	33
Constant	-876.300	17293.400	-269.140	-294.020	-134.070
INDEPENDENT VARIABLES					
X_3	15.678 *		5.564		7.954
X_6				2.524	
X_9		- 134.080			
X_{12}			15.695		18.033
X_{15}	1.319			0.994	
X_{18}	- 13.979	1559.800			
X_{19}	20.307		7.356	8.696	
X_{20}		- 4.526			
X_{21}		1.326			0.013
X_{24}		262.700			
X_{25}	- 0.133		- 0.067		- 0.072
X_{26}	0.010			0.002	
X_{28}			- 0.106	- 0.231	- 0.207
X_{56}		- 293.170			
r	0.574	0.548	0.557	0.496	0.623

* The coefficient underlined represents the variable that is the most significant in the regression equation.

TABLE 11 (Continued)

	Dependent Variables				
	34	35	36	37	38
Constant	-250.440	-808.600	-3029.600	-4467.400	-1135.520
INDEPENDENT VARIABLES					
X_3	2.929			17.710	
X_6				14.630	
X_9					
X_{12}		- 7.964	<u>108.900</u>	- 41.290	
X_{15}					
X_{18}			504.600	217.580	177.380
X_{19}		5.082		<u>64.100</u>	
X_{20}			- 0.416		- 0.155
X_{21}		0.007	0.113		
X_{24}	<u>6.772</u>	<u>12.317</u>	44.519	25.140	<u>35.018</u>
X_{25}	- 0.034	0.021		- 0.282	
X_{26}	- 0.005	0.005		0.061	
X_{28}	- 0.071		- 2.127		- 0.526
X_{56}	- 2.680				
r	0.564	0.528	0.613	0.602	0.471

TABLE 11 (Continued)

		Dependent Variables				
		39	40	41	42	43
	Constant	407.160	-862.990	-770.300	467.510	-8287.700
INDEPENDENT VARIABLES	X_3	10.550	34.760	1.187	38.800	- 86.810
	X_6		- 10.540		-28.830	87.146
	X_9	-11.880				
	X_{12}	17.324		53.240		
	X_{15}		5.420			
	X_{18}	170.580		220.280	353.450	
	X_{19}		26.670			145.770
	X_{20}	- 0.119		- 0.108	- 0.657	
	X_{21}			0.054	0.130	0.083
	X_{24}				-39.170	
	X_{25}	- 0.190	- 0.226			
	X_{26}					
	X_{28}	- 0.663	- 0.390	- 0.559	- 1.019	
	X_{56}		- 18.387			29.340
	r	0.478	0.564	0.448	0.568	0.698

TABLE 11 (Continued)

	Dependent Variables				
	44	45	46	47	48
Constant	-3987.200 -	-4318.000	-1143.400	-1613.000	-653.100
INDEPENDENT VARIABLES					
X_3		- 40.850	15.370	4.433	26.857
X_6	52.640	44.720			
X_9					
X_{12}				6.270	22.554
X_{15}	- 15.570		2.870		2.447
X_{18}		312.090	169.190		
X_{19}		73.620	28.560	6.396	
X_{20}	0.393		- 0.137		
X_{21}	0.094			0.030	
X_{24}				23.070	17.930
X_{25}	- 0.608		- 0.144		- 0.195
X_{26}	0.091	0.068		0.007	
X_{28}			- 0.465	- 0.150	- 0.628
X_{56}	89.423				
r	0.540	0.410	0.588	0.446	0.627

TABLE 11 (Continued)

		Dependent Variables				
		49	50	51	52	53
	Constant	-1938.500	-2840.930	-1308.700	-565.480	58876.100
INDEPENDENT VARIABLES	X_3		33.160	27.872		480.280
	X_6	6.143			5.725	
	X_9					
	X_{12}		26.147		8.250	
	X_{15}	3.572	10.476		1.073	76.248
	X_{18}				55.347	1984.250
	X_{19}	25.186	87.111	27.702	11.740	830.990
	X_{20}	- 0.111	- 0.276			
	X_{21}	0.036				
	X_{24}	16.948				508.720
	X_{25}	- 0.064	- 0.291	- 0.223	- 0.076	- 4.446
	X_{26}			0.032	0.007	
	X_{28}	- 0.208	- 0.888		- 0.212	- 9.095
	X_{56}	- 16.269	- 30.770			
	r	0.602	0.604	0.538	0.554	0.537

TABLE 11 (Continued)

		Dependent Variables	
		54	55
	Constant	-1560.280	-1325.000
INDEPENDENT VARIABLES	X_3	35.798	
	X_6		
	X_9		
	X_{12}		16.578
	X_{15}		
	X_{18}		285.750
	X_{19}	32.654	37.520
	X_{20}		- 0.249
	X_{21}		
	X_{24}		
	X_{25}	- 0.305	
	X_{26}	0.039	0.025
	X_{28}		- 1.138
	X_{56}		
	r	0.587	0.445

SIMPLE CORRELATION COEFFICIENTS FOR EACH VARIABLE AND ALL OTHER VARIABLES- NONINTERSECTIONS

CORRELATION MATRIX

VARIABLE NUMBER	1	2	3	4	5	6	7	8	9	10
1	1.000	0.260	0.845	0.933	0.229	0.744	0.061	0.161	0.153	0.024
2		1.000	0.737	0.293	0.978	0.767	0.390	-0.009	0.155	-0.095
3			1.000	0.816	0.703	0.946	0.259	0.108	0.193	-0.036
4				1.000	0.297	0.827	-0.015	0.191	0.145	-0.008
5					1.000	0.783	0.332	-0.009	0.131	-0.033
6						1.000	0.186	0.119	0.172	-0.025
7							1.000	0.303	0.657	-0.063
8								1.000	0.918	0.017
9									1.000	-0.013
10										1.000

VARIABLE NUMBER	11	12	13	14	15	16	17	18	19	20
1	0.421	0.301	0.056	0.240	-0.206	-0.392	0.299	0.424	-0.058	0.342
2	0.064	-0.032	0.269	-0.099	-0.417	-0.564	0.281	0.259	0.423	0.229
3	0.330	0.193	0.188	0.113	-0.376	-0.587	0.365	0.440	0.193	0.367
4	0.279	0.173	-0.060	0.413	-0.162	-0.411	0.277	0.465	-0.190	0.258
5	-0.011	-0.039	0.244	-0.030	-0.380	-0.539	0.314	0.277	0.352	0.172
6	0.176	0.090	0.105	0.251	-0.329	-0.585	0.366	0.466	0.084	0.269
7	0.095	0.014	0.192	-0.614	-0.336	-0.342	0.244	-0.027	0.543	0.310
8	0.015	0.003	-0.129	0.021	-0.117	-0.342	0.370	0.253	-0.101	0.120
9	0.051	0.009	-0.022	-0.239	-0.232	-0.413	0.394	0.189	0.146	0.224
10	-0.097	0.701	-0.173	-0.004	0.415	0.070	0.235	-0.059	-0.222	-0.188
11	1.000	0.634	-0.104	-0.072	-0.041	-0.094	0.115	0.025	0.213	-0.061
12		1.000	-0.208	-0.065	0.279	0.008	0.257	-0.041	-0.014	-0.200
13			1.000	-0.048	-0.407	-0.138	-0.105	0.369	0.184	0.773
14				1.000	0.238	-0.010	-0.180	0.364	-0.814	-0.022
15					1.000	0.452	-0.010	-0.185	-0.500	-0.439
16						1.000	-0.165	-0.387	-0.293	-0.403
17							1.000	0.384	0.137	0.124
18								1.000	-0.195	0.572
19									1.000	0.185
20										1.000

TABLE 12 (CONTINUED)

VARIABLE NUMBER	21	22	23	24	25	26	27	28	29	30
1	0.215	0.855	-0.002	-0.372	0.698	-0.335	-0.312	-0.052	0.416	0.133
2	0.347	0.287	0.352	-0.525	0.697	-0.503	-0.453	-0.174	0.181	0.115
3	0.343	0.758	0.196	-0.551	0.875	-0.514	-0.470	-0.133	0.392	0.157
4	0.252	0.816	0.049	-0.480	0.706	-0.337	-0.303	-0.084	0.390	0.189
5	0.359	0.268	0.356	-0.537	0.689	-0.457	-0.409	-0.162	0.163	0.144
6	0.376	0.689	0.242	-0.629	0.866	-0.489	-0.438	-0.150	0.350	0.209
7	0.011	0.048	0.211	-0.518	0.200	-0.218	-0.124	-0.178	0.132	0.156
8	0.429	0.053	0.403	-0.493	0.043	0.019	0.095	0.102	-0.016	0.031
9	0.594	0.062	0.407	-0.606	0.118	-0.076	0.023	0.006	0.042	0.090
10	-0.111	0.060	-0.020	0.072	0.076	0.427	0.390	0.371	-0.064	-0.084
11	-0.076	0.105	-0.067	0.123	-0.000	-0.132	-0.115	0.231	0.478	0.046
12	-0.157	0.106	-0.065	0.174	0.047	0.231	0.214	0.453	0.277	-0.042
13	0.240	0.244	-0.004	-0.105	0.242	-0.481	-0.491	-0.181	-0.189	-0.236
14	-0.308	0.220	-0.099	0.002	0.121	-0.156	-0.204	0.205	-0.101	-0.101
15	-0.122	-0.144	-0.232	0.110	-0.267	0.740	0.716	0.412	-0.016	-0.010
16	-0.035	-0.344	-0.244	0.576	-0.513	0.621	0.568	0.075	-0.083	0.074
17	0.418	0.278	0.279	-0.424	0.404	0.128	0.179	0.276	0.163	0.262
18	0.245	0.527	0.078	-0.421	0.520	-0.455	-0.444	0.333	-0.046	0.064
19	0.313	-0.051	0.163	-0.117	0.145	-0.219	-0.152	-0.338	0.253	0.157
20	0.423	0.506	0.041	-0.387	0.441	-0.548	-0.535	-0.152	-0.076	-0.127
21	1.000	0.263	0.167	-0.753	0.330	-0.061	0.057	-0.142	0.194	0.303
22		1.000	-0.002	-0.386	0.856	-0.280	-0.265	-0.070	0.245	0.075
23			1.000	-0.313	0.224	-0.108	-0.073	-0.109	-0.075	-0.036
24				1.000	-0.551	0.306	0.206	0.104	-0.123	-0.127
25					1.000	-0.397	-0.367	-0.117	0.237	0.126
26						1.000	0.985	0.135	0.002	0.124
27							1.000	0.135	0.047	0.177
28								1.000	-0.181	-0.072
29									1.000	0.601
30										1.000

TABLE 12 (CONTINUED)

VARIABLE NUMBER	31	32	33	34	35	36	37	38	39	40
1	0.404	0.213	0.458	-0.034	-0.160	0.297	0.259	-0.119	0.066	0.325
2	0.027	0.264	0.261	-0.092	-0.230	0.038	0.221	-0.169	0.111	0.231
3	0.298	0.296	0.466	-0.075	-0.240	0.229	0.304	-0.177	0.107	0.356
4	0.328	0.251	0.439	-0.077	-0.192	0.243	0.273	-0.114	0.057	0.239
5	0.026	0.237	0.245	-0.136	-0.247	0.032	0.215	-0.146	0.071	0.155
6	0.229	0.304	0.431	-0.130	-0.270	0.177	0.305	-0.160	0.079	0.247
7	0.084	0.098	0.235	-0.100	-0.230	0.075	0.169	-0.269	-0.117	0.211
8	-0.006	-0.018	0.087	-0.175	-0.215	-0.007	0.022	-0.210	-0.165	0.039
9	0.030	0.026	0.167	-0.180	-0.266	0.025	0.088	-0.278	-0.179	0.119
10	-0.010	-0.136	-0.040	-0.071	-0.132	0.063	-0.159	-0.053	-0.114	-0.101
11	0.622	0.072	0.598	0.208	-0.137	0.528	0.097	0.077	0.339	0.378
12	0.429	-0.069	0.381	0.089	-0.198	0.414	-0.069	0.011	0.154	0.185
13	-0.186	-0.105	-0.135	-0.165	-0.004	-0.190	-0.206	-0.090	-0.115	0.056
14	-0.095	-0.060	-0.029	-0.093	-0.159	-0.103	-0.222	0.060	-0.008	-0.115
15	-0.034	-0.041	-0.059	-0.037	0.012	0.047	-0.162	0.034	0.052	-0.052
16	-0.078	-0.082	-0.244	0.167	0.198	-0.074	-0.082	0.135	0.031	-0.147
17	0.202	0.003	0.176	-0.187	-0.163	0.093	0.256	-0.170	-0.248	-0.045
18	-0.028	-0.037	0.055	-0.236	-0.182	-0.102	0.015	-0.185	-0.117	0.014
19	0.222	0.198	0.245	0.083	0.118	0.210	0.305	-0.036	0.124	0.211
20	-0.033	-0.039	-0.014	-0.194	-0.057	-0.145	-0.052	-0.244	-0.168	0.119
21	0.077	0.202	0.214	-0.253	-0.120	0.060	0.290	-0.282	-0.128	0.135
22	0.176	0.191	0.258	-0.126	-0.061	0.095	0.193	-0.136	-0.040	0.239
23	-0.079	-0.039	0.001	-0.134	-0.177	-0.103	-0.008	-0.131	-0.069	-0.055
24	0.010	-0.159	-0.225	0.407	0.341	0.052	-0.158	0.404	0.106	-0.135
25	0.122	0.241	0.285	-0.183	-0.164	0.058	0.245	-0.172	-0.041	0.198
26	-0.008	0.001	-0.135	0.166	0.216	0.097	0.042	0.176	-0.019	-0.105
27	0.021	0.037	-0.078	0.139	0.190	0.118	0.089	0.133	-0.030	-0.062
28	-0.011	-0.331	-0.088	-0.180	-0.191	-0.126	-0.226	-0.110	-0.179	-0.140
29	0.828	0.697	0.892	0.369	0.072	0.852	0.623	0.233	0.464	0.501
30	0.491	0.455	0.439	0.302	0.162	0.417	0.741	0.032	0.048	0.157
31	1.000	0.210	0.857	0.223	-0.018	0.794	0.427	0.200	0.217	0.354
32		1.000	0.485	0.503	0.307	0.565	0.652	0.155	0.529	0.415
33			1.000	0.214	-0.184	0.827	0.462	0.174	0.370	0.506
34				1.000	0.416	0.497	0.483	0.126	0.469	0.356
35					1.000	0.171	0.395	0.177	-0.005	-0.111
36						1.000	0.446	0.268	0.409	0.398
37							1.000	0.015	0.188	0.276
38								1.000	0.018	-0.131
39									1.000	0.505
40										1.000

TABLE 12 (CONTINUED)

VARIABLE NUMBER	41	42	43	44	45	46	47	48	49	50
1	0.375	0.236	0.170	0.216	0.105	0.415	0.140	0.501	0.193	0.291
2	0.025	0.165	0.441	0.283	0.181	0.178	0.032	0.180	0.125	0.204
3	0.265	0.257	0.364	0.308	0.174	0.389	0.115	0.451	0.205	0.317
4	0.322	0.243	0.276	0.235	0.176	0.408	0.107	0.431	0.224	0.261
5	0.014	0.189	0.490	0.328	0.210	0.173	0.016	0.141	0.136	0.171
6	0.218	0.269	0.468	0.347	0.238	0.368	0.077	0.364	0.226	0.271
7	0.187	0.234	0.314	0.260	0.105	0.079	0.139	0.090	0.118	0.136
8	0.104	0.225	0.078	0.114	-0.027	0.026	-0.108	-0.040	-0.010	-0.000
9	0.160	0.276	0.192	0.198	0.023	0.054	-0.028	0.006	0.041	0.056
10	0.043	-0.018	-0.130	0.012	0.064	-0.078	-0.031	-0.028	-0.102	0.067
11	0.408	-0.089	-0.083	-0.066	-0.050	0.373	0.308	0.526	0.295	0.369
12	0.314	-0.036	-0.169	-0.044	0.009	0.189	0.186	0.341	0.119	0.303
13	-0.059	-0.187	-0.149	-0.117	-0.090	-0.247	-0.026	-0.128	-0.220	-0.218
14	-0.059	-0.146	-0.140	-0.112	-0.092	-0.061	-0.155	-0.068	-0.129	-0.170
15	-0.009	-0.041	-0.198	-0.157	0.023	-0.036	-0.011	-0.064	0.066	0.052
16	-0.138	-0.126	-0.227	-0.143	-0.044	-0.150	0.036	-0.086	-0.033	-0.062
17	0.249	0.369	0.352	0.310	0.324	0.190	0.037	0.114	0.167	0.101
18	0.118	0.024	0.101	0.014	0.101	0.000	-0.107	0.051	-0.151	-0.105
19	0.150	0.160	0.340	0.198	0.091	0.230	0.204	0.183	0.276	0.273
20	0.051	-0.014	0.027	0.009	-0.012	-0.087	-0.063	-0.030	-0.128	-0.121
21	0.206	0.434	0.447	0.368	0.226	0.202	0.072	0.076	0.276	0.171
22	0.242	0.140	0.163	0.096	0.121	0.228	0.133	0.313	0.086	0.145
23	-0.035	0.034	0.174	0.096	0.063	-0.043	-0.130	-0.073	-0.065	-0.046
24	-0.143	-0.409	-0.442	-0.288	-0.205	-0.163	0.130	-0.051	-0.159	-0.113
25	0.208	0.201	0.362	0.214	0.190	0.251	0.074	0.273	0.118	0.174
26	-0.036	0.083	-0.126	-0.028	0.085	-0.016	0.123	-0.079	0.113	0.073
27	0.002	0.153	-0.054	0.022	0.118	0.028	0.139	-0.061	0.173	0.117
28	0.034	-0.174	-0.210	-0.134	0.001	-0.193	-0.121	-0.149	-0.187	-0.132
29	0.645	0.326	0.392	0.373	0.204	0.911	0.623	0.902	0.862	0.868
30	0.412	0.530	0.552	0.551	0.336	0.577	0.382	0.498	0.578	0.561
31	0.761	0.195	0.218	0.271	0.157	0.785	0.475	0.763	0.696	0.629
32	0.175	0.316	0.407	0.313	0.077	0.595	0.480	0.626	0.599	0.707
33	0.703	0.175	0.330	0.277	0.124	0.817	0.544	0.816	0.747	0.758
34	-0.017	-0.067	-0.024	0.058	-0.006	0.208	0.311	0.399	0.236	0.435
35	-0.046	0.141	-0.028	-0.065	0.059	0.016	0.189	0.030	0.109	0.031
36	0.631	0.118	0.232	0.250	0.082	0.738	0.585	0.783	0.713	0.780
37	0.339	0.461	0.500	0.476	0.306	0.590	0.378	0.537	0.567	0.585
38	0.216	-0.066	-0.122	-0.110	0.016	0.285	0.629	0.157	0.253	0.111
39	-0.089	-0.042	0.062	-0.071	-0.027	0.328	0.249	0.500	0.341	0.528
40	-0.033	0.026	0.058	0.032	0.062	0.345	0.299	0.589	0.260	0.583
41	1.000	0.131	0.205	0.261	0.018	0.679	0.387	0.528	0.617	0.410
42		1.000	0.464	0.476	0.301	0.376	0.119	0.210	0.377	0.289
43			1.000	0.727	0.239	0.459	0.136	0.258	0.447	0.337
44				1.000	0.131	0.469	0.064	0.289	0.375	0.368
45					1.000	0.156	0.248	0.087	0.290	0.193
46						1.000	0.436	0.810	0.804	0.756
47							1.000	0.546	0.545	0.532
48								1.000	0.570	0.820
49									1.000	0.704
50										1.000

TABLE 12 (CONTINUED)

VARIABLE NUMBER	51	52	53	54	55	56
1	0.424	0.389	0.288	0.427	-0.002	-0.403
2	0.153	0.085	0.185	0.201	0.055	-0.329
3	0.382	0.320	0.305	0.410	0.029	-0.464
4	0.396	0.390	0.241	0.384	-0.004	-0.389
5	0.157	0.120	0.118	0.185	0.050	-0.263
6	0.351	0.325	0.226	0.359	0.027	-0.408
7	0.203	0.069	0.140	0.203	0.047	-0.237
8	0.035	0.046	-0.084	0.052	-0.129	-0.188
9	0.112	0.065	-0.008	0.126	-0.083	-0.248
10	-0.055	0.052	-0.164	0.022	-0.021	0.277
11	0.447	0.332	0.463	0.456	0.101	-0.041
12	0.262	0.262	0.197	0.329	0.041	0.183
13	-0.164	-0.230	-0.062	-0.191	-0.118	-0.580
14	-0.125	-0.007	-0.161	-0.135	-0.184	-0.137
15	-0.055	0.081	-0.108	-0.020	0.032	0.710
16	-0.099	-0.079	-0.033	-0.111	0.101	0.491
17	0.276	0.288	-0.060	0.205	-0.052	-0.071
18	0.003	-0.002	-0.080	-0.026	-0.186	-0.588
19	0.234	0.124	0.284	0.246	0.206	-0.141
20	-0.048	-0.127	0.009	-0.068	-0.175	-0.765
21	0.263	0.224	0.080	0.228	0.054	-0.126
22	0.246	0.205	0.194	0.237	-0.059	-0.426
23	-0.037	-0.065	-0.075	-0.050	-0.087	-0.129
24	-0.148	-0.169	0.014	-0.152	0.075	0.302
25	0.243	0.208	0.156	0.248	-0.047	-0.430
26	0.011	0.097	-0.095	0.009	0.163	0.773
27	0.054	0.142	-0.067	0.054	0.203	0.751
28	-0.163	-0.113	-0.185	-0.137	-0.262	0.155
29	0.916	0.836	0.796	0.947	0.399	0.024
30	0.614	0.536	0.443	0.568	0.277	0.078
31	0.654	0.772	0.575	0.790	0.222	0.033
32	0.528	0.480	0.661	0.653	0.396	-0.010
33	0.667	0.771	0.680	0.877	0.305	-0.087
34	0.240	0.173	0.455	0.356	0.208	0.074
35	0.002	0.011	0.119	-0.019	0.115	0.134
36	0.812	0.773	0.615	0.878	0.290	0.109
37	0.588	0.458	0.565	0.577	0.369	-0.013
38	0.256	0.295	0.086	0.171	0.327	0.158
39	0.243	0.232	0.553	0.410	0.402	0.127
40	0.304	0.173	0.666	0.461	0.429	-0.129
41	0.774	0.744	0.288	0.688	-0.030	-0.067
42	0.320	0.433	0.085	0.258	0.245	0.034
43	0.426	0.342	0.277	0.425	0.142	-0.037
44	0.423	0.391	0.192	0.466	0.055	0.014
45	0.226	0.289	0.037	0.114	0.287	0.017
46	0.874	0.823	0.651	0.879	0.348	0.024
47	0.580	0.510	0.518	0.559	0.504	0.042
48	0.797	0.650	0.832	0.879	0.360	-0.050
49	0.824	0.841	0.554	0.785	0.331	0.146
50	0.680	0.659	0.771	0.880	0.466	0.098
51	1.000	0.845	0.636	0.898	0.291	0.011
52		1.000	0.338	0.801	0.309	0.097
53			1.000	0.740	0.360	-0.063
54				1.000	0.303	0.032
55					1.000	0.157
56						1.000

TABLE 13

VARIABLE MEANS AND STANDARD DEVIATIONS-NONINTERSECTIONS

VARIABLE	MEAN	STANDARD DEVIATION
1	9.01389	12.12202
2	7.77778	9.59492
3	16.79167	17.30663
4	12.65278	15.11380
5	10.90278	13.65692
6	23.55556	23.18443
7	8.50000	2.74247
8	10.54167	5.20817
9	19.04167	6.58089
10	1.58333	3.97439
11	0.87500	3.64610
12	2.58333	5.09280
13	2.29167	0.68046
14	0.53333	1.21667
15	39.29167	41.93000
16	1.23417	1.24759
17	0.43056	0.60109
18	1.08333	0.57531
19	43.54167	3.79004
20	1040.95833	716.25143
21	15566.87500	2830.06610
22	545.15277	835.99813
23	512.91666	1153.96111
24	41.62916	5.56079
25	927.02777	1058.66983
26	9591.29163	5699.40509
27	6.50000	3.47628
28	138.22222	229.00753
29	278.50000	279.26157
30	3382.58331	3992.32022
31	108.23611	195.39869
32	171.93056	162.79471
33	146.69444	229.43888
34	38.54167	76.68848
35	75.44444	122.52344
36	677.01389	897.60001
37	459.76389	569.65847
38	280.19444	450.67982
39	195.62500	375.50904
40	248.51389	450.19886
41	282.38889	641.74617
42	391.62500	910.56309
43	482.59722	1407.81519
44	446.29166	1653.64517
45	246.40278	1195.55408
46	313.72222	331.65855
47	226.87500	259.56738
48	431.36111	514.84139
49	206.76389	214.61418
50	747.73611	858.56983
51	466.50000	529.91608
52	168.68056	181.68969
53	6315.12500	9259.86035
54	555.50000	601.28410
55	483.19444	645.83214
56	18.19143	6.23739

the practical capacity (X_{20}), the ADT (X_{21}), the operating speed (X_{24}) and a measure of congestion (X_{56}).

Injury accident rates (Y_{31}) were influenced most by commercial development (X_3 and X_{25}), low volume intersections per mile (X_{12}) and the length of turning lanes in the section (X_{28}).

The property-damage-only accident rates (Y_{32}) were affected by the percent no-passing zones (X_{15}) and the distance from the extremities of the by-pass (X_{26}) in addition to the number of driveways per mile (X_6) and the length of turning lanes in the section (X_{28}).

Type II accident rates (Y_{33}) were influenced most by commercial development (X_3 and X_{25}), the ADT (X_{21}), the number of low volume intersections per mile (X_{12}) and the length of turning lanes in the section (X_{28}).

The most significant variable in predicting Type III (Y_{34}) and Type IV (Y_{35}) accident rates was the operating speed (X_{24}). Commercial development was also significant for each of these two rates.

Independent variables that appear in the regression equations for both northwest bound (Y_{36}) and southeast bound (Y_{37}) traffic are low volume intersections per mile (X_{12}), number of intersections adjacent to the section (X_{18}) and the operating speed (X_{24}). Other variables affecting southeast bound vehicles were commercial development (X_3, X_6, and X_{25}), geometric modulus (X_{19}) and the distance from the extremities of the by-pass (X_{26}) while those affecting northwest bound vehicles were practical capacity (X_{20}), the ADT (X_{21}) and the length of the turning lanes in the section (X_{28}).

Accident rates during hours having volumes greater than 600 vph were always affected by commercial development (either X_3, X_6, or X_{25}) while the ADT (X_{21}) was also a significant variable for hours with volumes greater than 1000 vph. The number of intersections adjacent to the section (X_{18}) and the length of turning lanes in the section (X_{28}) were other significant variables for hours with volumes less than 1400 vph. Further, the measure of congestion (X_{56}) was significant for hours with volumes between 1400 - 1800 vph.

Operating speed (X_{24}) was always a significant night accident rate (Y_{47}) variable while practical capacity was significant for day accident rates (Y_{46}).

Weekday accident rates (Y_{49}) were affected by practical capacity (X_{20}), the ADT (X_{21}) and the measure of congestion (X_{56}) while weekend accident rates (Y_{48}) were influenced by the number of establishments per mile (X_3) and the number of low volume intersections per mile (X_{12}).

The percentage of no-passing zones (X_{15}), practical capacity (X_{20}) and a measure of congestion (X_{56}) were significant independent variables for predicting Tippecanoe County driver involvement rates (Y_{50}). Both county and out-of-county driver (Y_{51}) involvement rates were affected by commercial development (X_3 and X_{25}). Out-of-county driver involvement rate was affected by the distance from the extremities of the by-pass (X_{26}).

Clear (Y_{52}) and inclement weather (Y_{53}) accident rates were influenced by nearly the same variables, however, the operating speed was significant in rainy and snowy weather accidents but not in clear weather accidents.

Although commercial development (X_3 and X_{25}) influenced passenger car (Y_{54}) accident rates, these variables were not significant in truck accident rates (Y_{55}). Practical capacity was a significant variable in predicting truck accident rates.

The variable that was the most significant in each nonintersection multiple linear regression equation is underlined in Table 11. The variable that is underlined most frequently is the number of establishments per mile (X_3).

Quality Control

Quality control analysis of highway accidents has been used in several studies. (Norden, Orlansky, and Jacobs, 1956 and Blindauer, 1958). The method is useful in determining sections of highway that have a much higher accident rate than that due to chance alone.

In applying the quality control method of analysis to highway accident data, the following expressions were used:

$$n_i = (ADT)(365)(10^{-6}) \text{ for intersections}$$

$$n_i = (ADT)(365)(L)(10^{-6}) \text{ for nonintersection sections}$$

$$p_i = \frac{a_i}{n_i}$$

$$\bar{p} = \frac{\Sigma a_i}{\Sigma n_i}$$

$$s_i = \sqrt{\frac{\bar{p}\,(1-\bar{p})}{n_i}} \text{ or } \sqrt{\frac{\bar{p}}{n_i}}$$

$$CL_i = \bar{p} \pm 3_{s_i}$$

where

i = The number of the section considered

n_i = The number of million vehicles passing through an intersection or the number of million vehicle miles in a section

a_i = The number of accidents per year in a section

$\bar{p}$ = The over-all accident rate for a particular group of intersections or sections,

s_i = The estimate of the standard deviation for an intersection or section,

CL_i = The upper or lower control limit for p_i on any intersection or section,

L = Length of section in miles,

ADT = Annual average daily traffic volume.

The expression for $(1-\bar{p})$ was eliminated from the expression for s_i since $(1-\bar{p})$ very nearly approaches unity.

The by-pass sections were divided into three classifications: signalized intersections, nonsignalized intersections, and nonintersection sections. For each of these groups an average accident rate, $\bar{p}$, was calculated for the three year period. For each section p_i, n_i, a_i, s_i, UCL_i, and LCL_i were calculated and plotted. In this manner any section that was out of control was detected by visual inspection of the control chart. A section out of control was one in which the accident rate was above or below a control limit. When a section fell out of the confidence bands, it was assumed that there was an assignable cause that explained the high accident rate.

Intersections

Figures 16, 17 and 18 are quality control charts for accident rates at signalized intersections in 1961, 1962 and 1963 respectively. Intersections 3, 13 and 14 were not signalized in 1961 and 1962.

Intersection number 14, Teal Road, was the only signalized intersection to be out of control. Intersection number 8, Greenbush, had a low

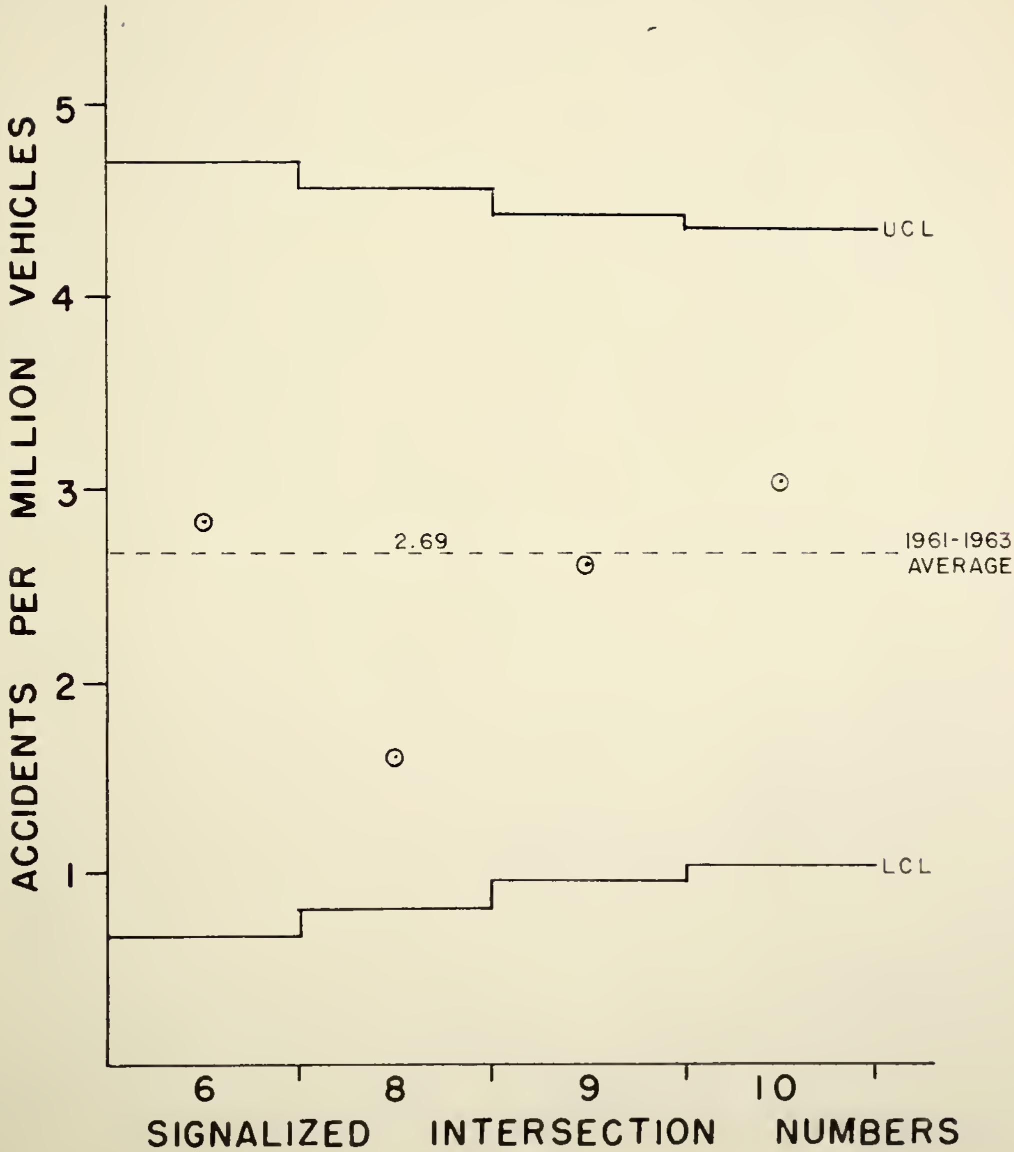


FIGURE 16 QUALITY CONTROL CHART FOR SIGNALIZED INTERSECTIONS, 1961.

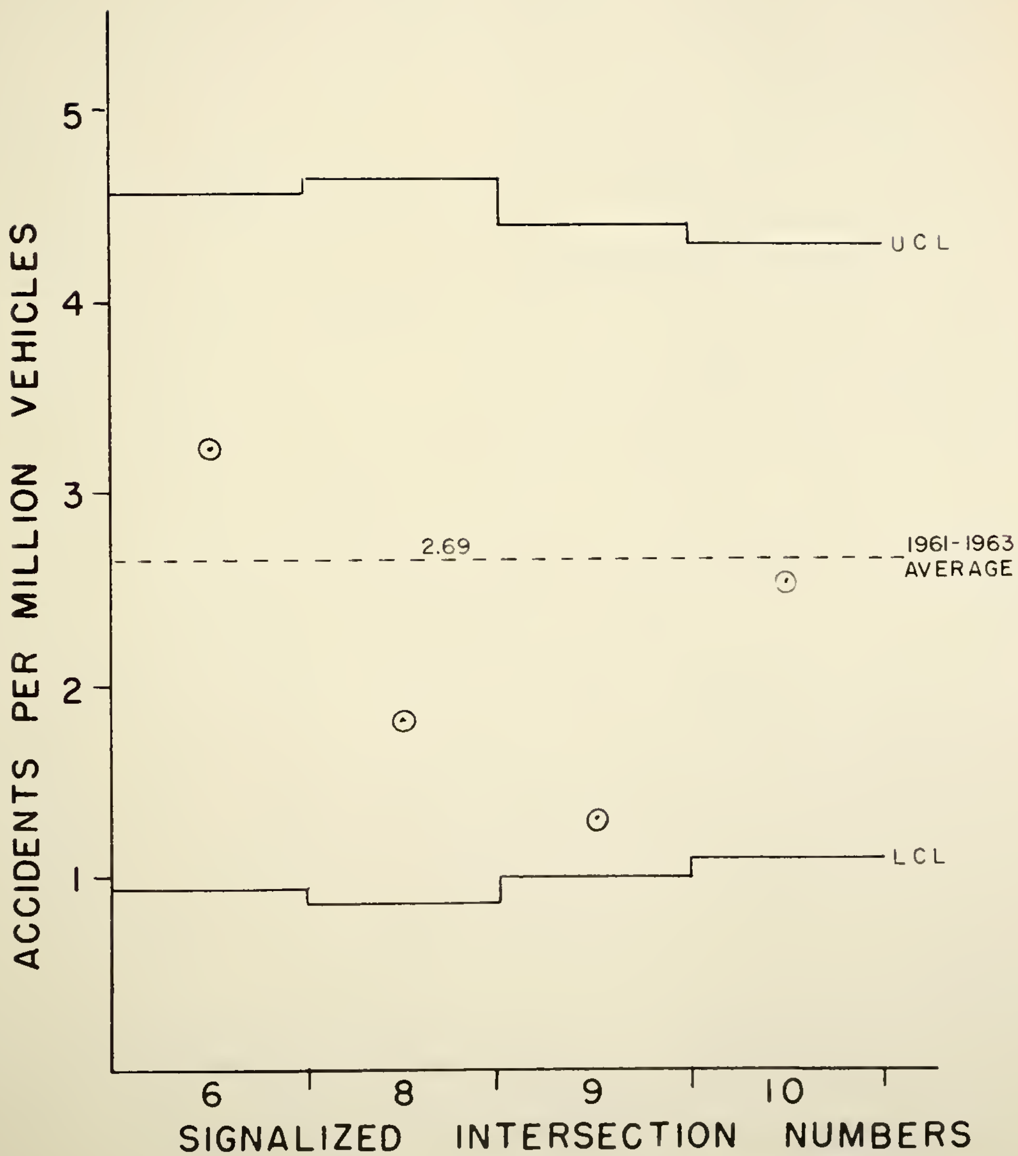


FIGURE 17 QUALITY CONTROL CHART FOR SIGNALIZED INTERSECTIONS, 1962.

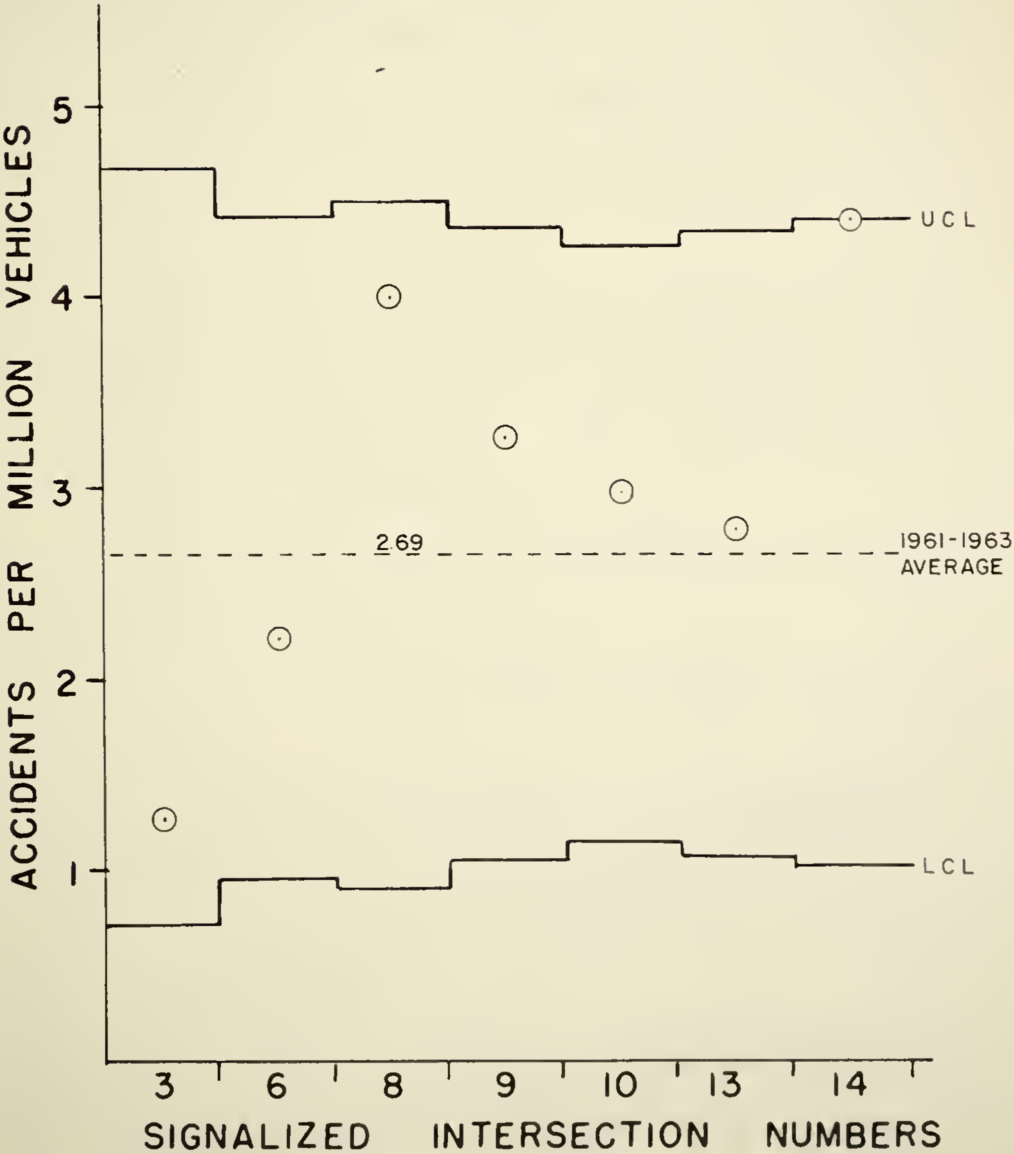


FIGURE 18 QUALITY CONTROL CHART FOR SIGNALIZED INTERSECTIONS, 1963.

accident rate the first two years but in 1963 the rate was very near the upper control limit. In 1962 Union Street, number 9, nearly fell below the lower control limit.

Collision-condition diagrams and field observations proved to be very useful in determining the assignable causes for the intersection that was out of control, Teal Road, and for determining causes for the large fluctuations in accident rates between years for Greenbush and Union Streets. These results are reported later in the section on collision-condition diagrams.

Figures 19, 20 and 21 are quality control charts for accident rates at nonsignalized intersections. The lower control limit is zero for many of these sections. Intersections 3, 13 and 14 were signalized in 1963 and therefore were not used in this analysis for that year.

Intersection 14, Teal Road, was just outside the upper control limit in 1961 and was also out of control in 1962.

Intersections 2, 7, 11 and 12 had accident rates below average for three consecutive years.

Intersections 13 and 14 were consistantly above the nonsignalized intersection average accident rate prior to the installation of traffic signals and were above the signalized intersection average accident rate after the signals were installed.

These intersections were also analyzed further by use of collision-condition diagrams and field observations. These results are given in a later section on collision-condition diagrams.

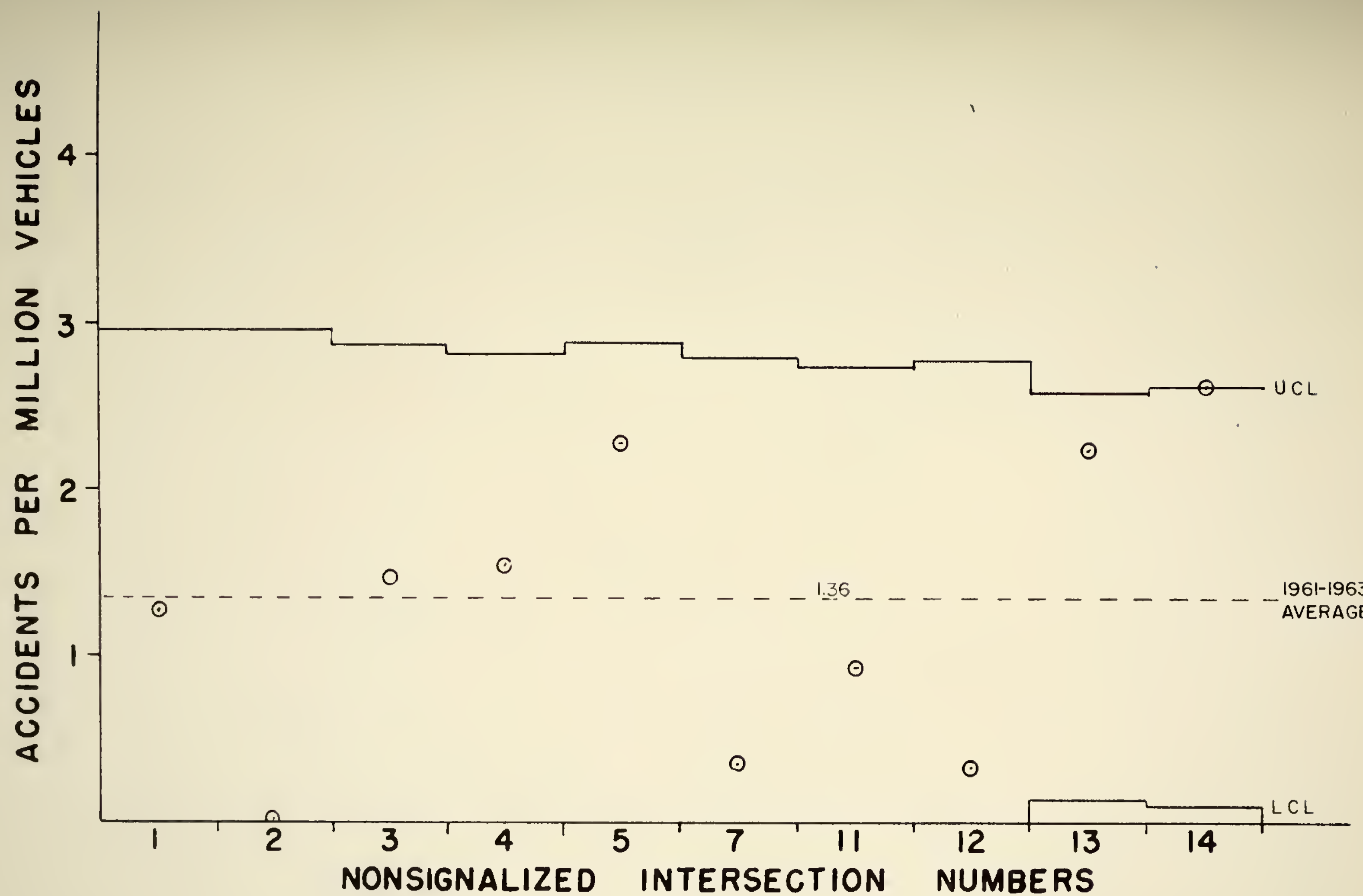


FIGURE 19 QUALITY CONTROL CHART FOR NONSIGNALIZED INTERSECTION, 1961.

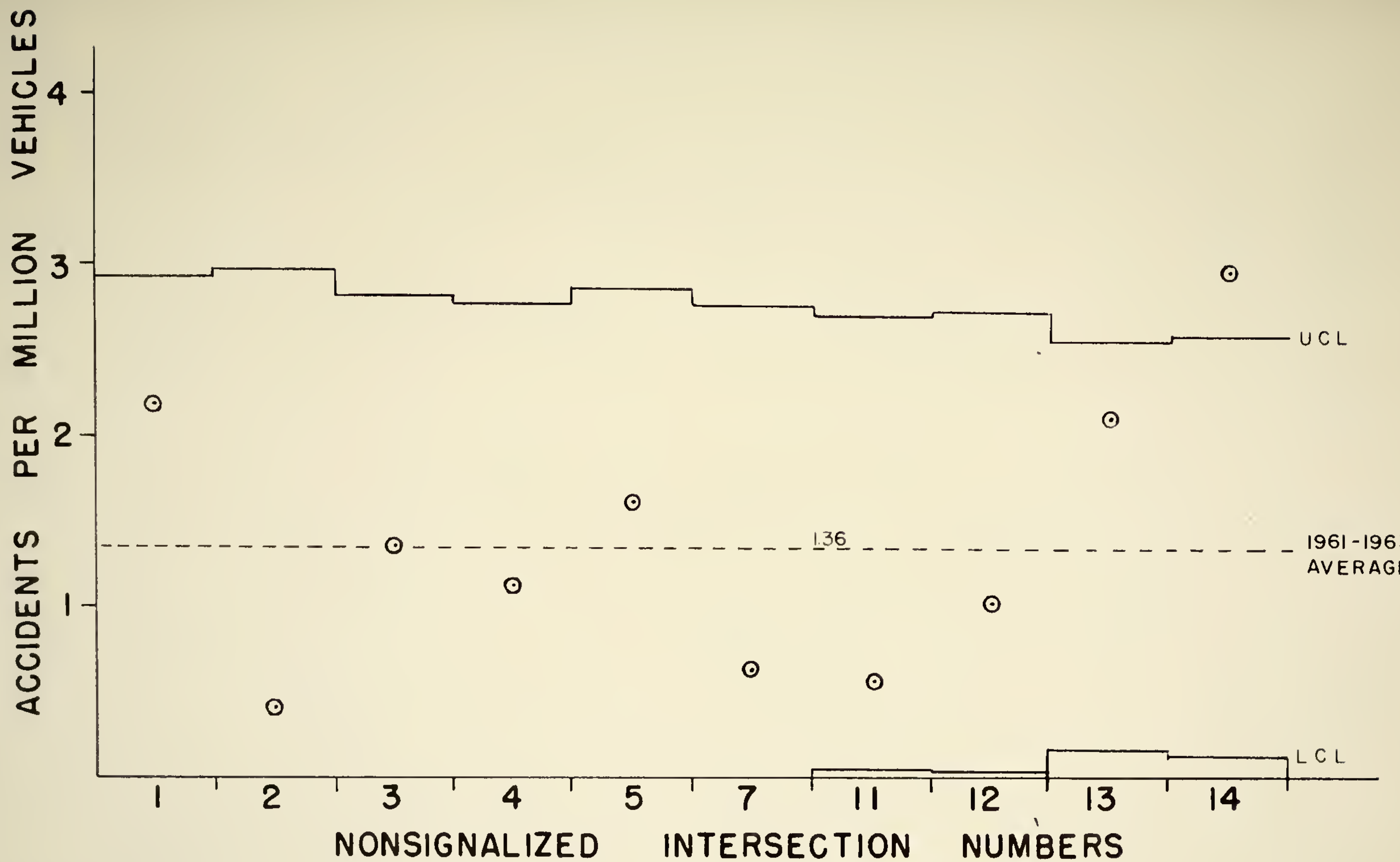


FIGURE 20 QUALITY CONTROL CHART FOR NONSIGNALIZED INTERSECTION, 1962.

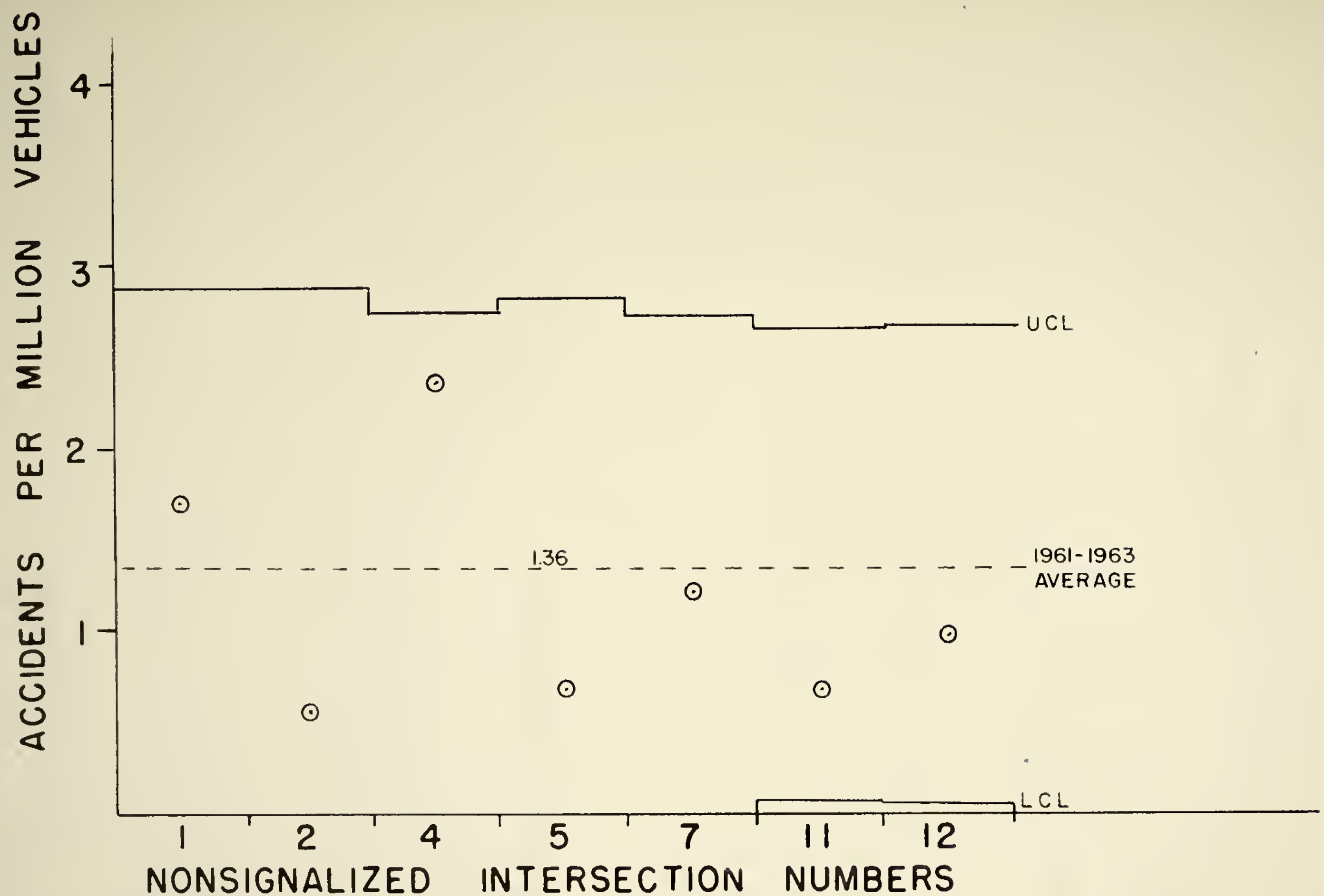


FIGURE 21 QUALITY CONTROL CHART FOR NONSIGNALIZED INTERSECTION, 1963.

Nonintersections

Figures 22 through 27 are quality control charts for accident rates of nonintersection study sections. The lower limit is zero for all sections. The length of each section is represented to a scale on the abscissa of one inch equals three thousand feet in these figures.

Section 4 in 1961 and 1962 was out of control but in 1963 had no accidents. Sections 18 and 19 were out of control in 1963. For the three year study period the following sections were either consistantly below or consistantly above the average accident rate.

Always Below Average	Always Above Average
2	14
5	17
6	18
8	19
10	21
16	
20	
24	

The characteristics of each section were studied by field observations to determine the assignable causes for the sections with accident rates above average, below average, and out of control. Collision diagrams provided a significant part of this analysis. These results are given in the section on collision diagrams.

Accident Rates

Intersections

Many different accident rates have been used in previous studies to represent the hazardousness of an intersection or section of highway. In this study many of these accident rates were computed and evaluated.

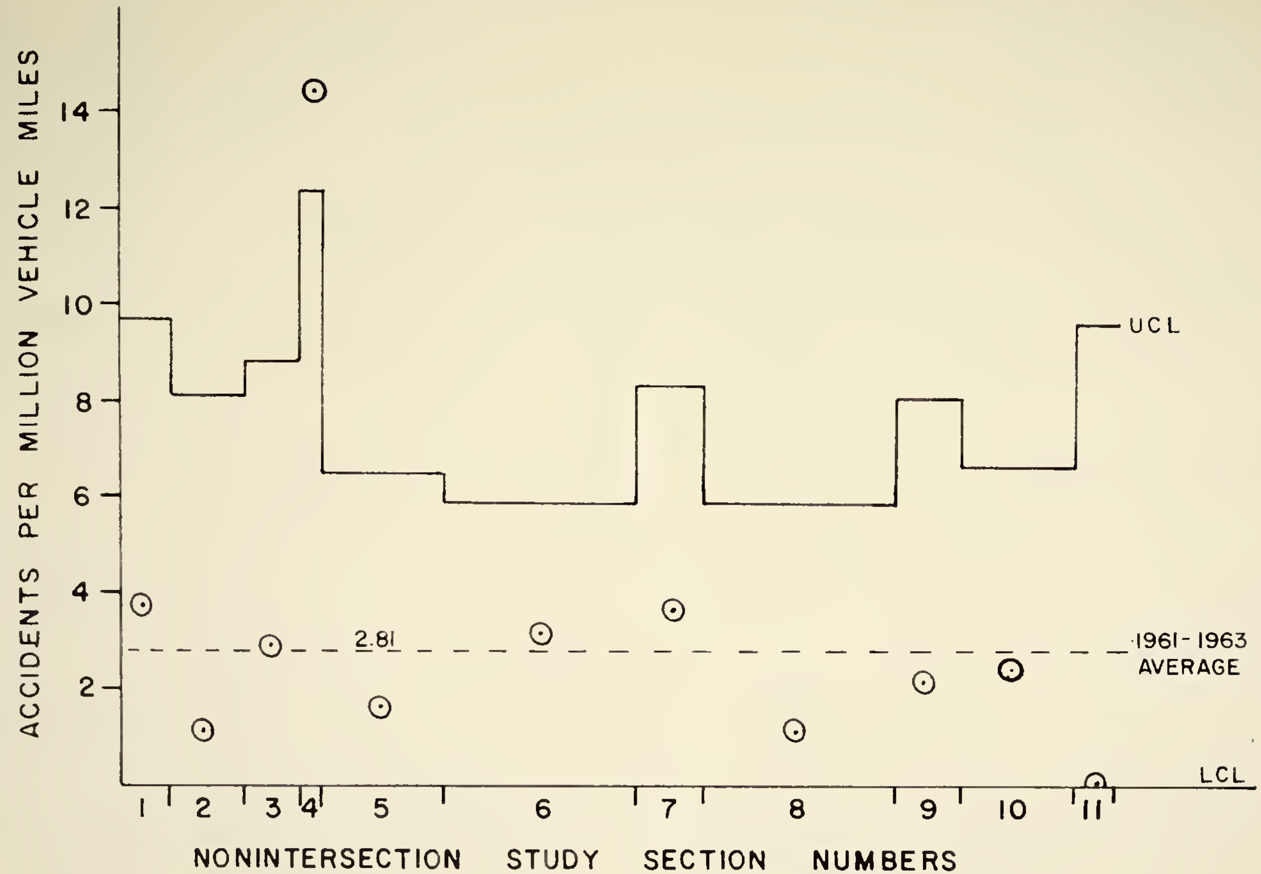


FIGURE 22 QUALITY CONTROL CHART FOR NONINTERSECTION STUDY SECTIONS, 1-11, 1961.

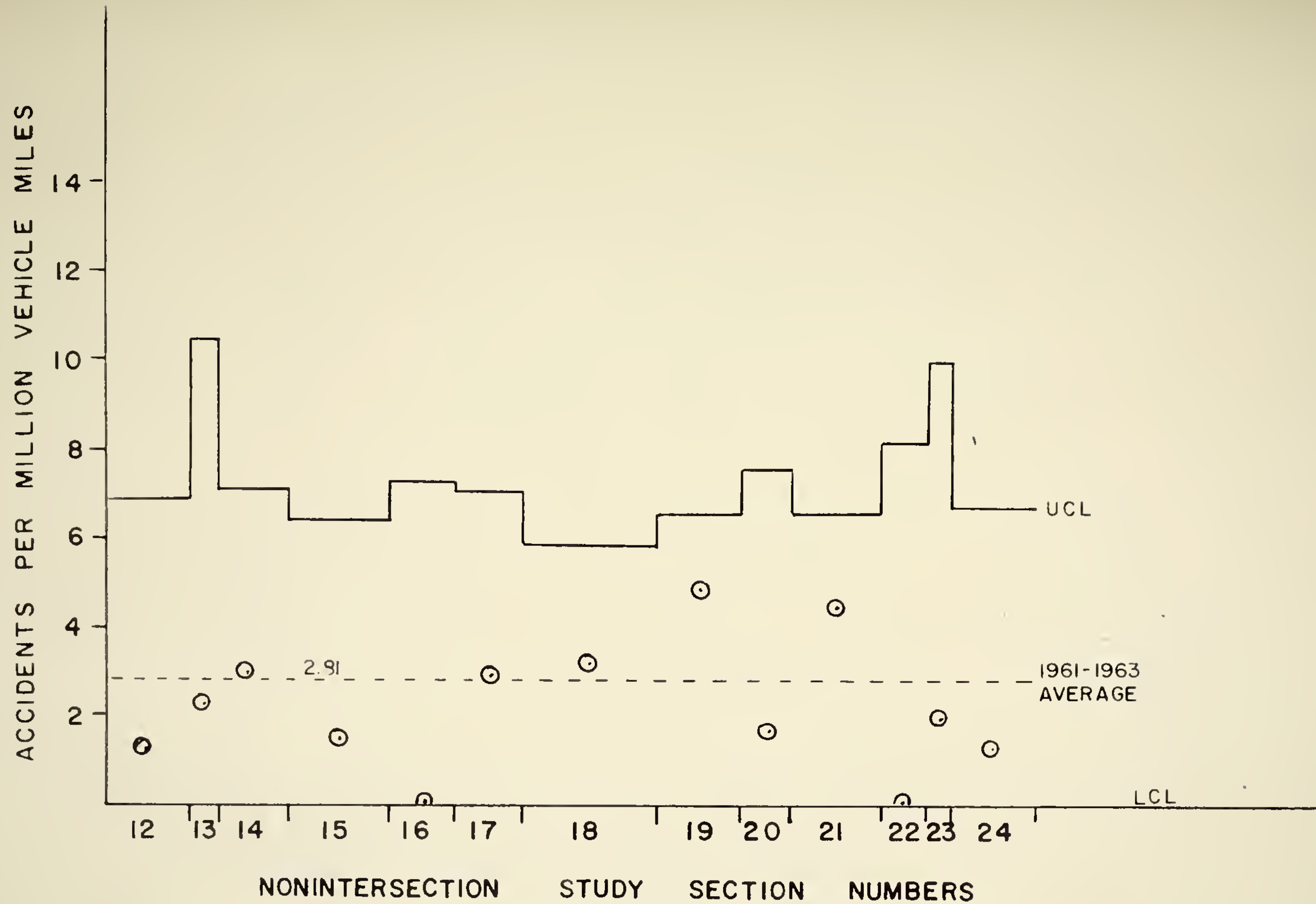


FIGURE 23 QUALITY CONTROL CHART FOR NONINTERSECTION STUDY SECTIONS, 12-24, 1961.

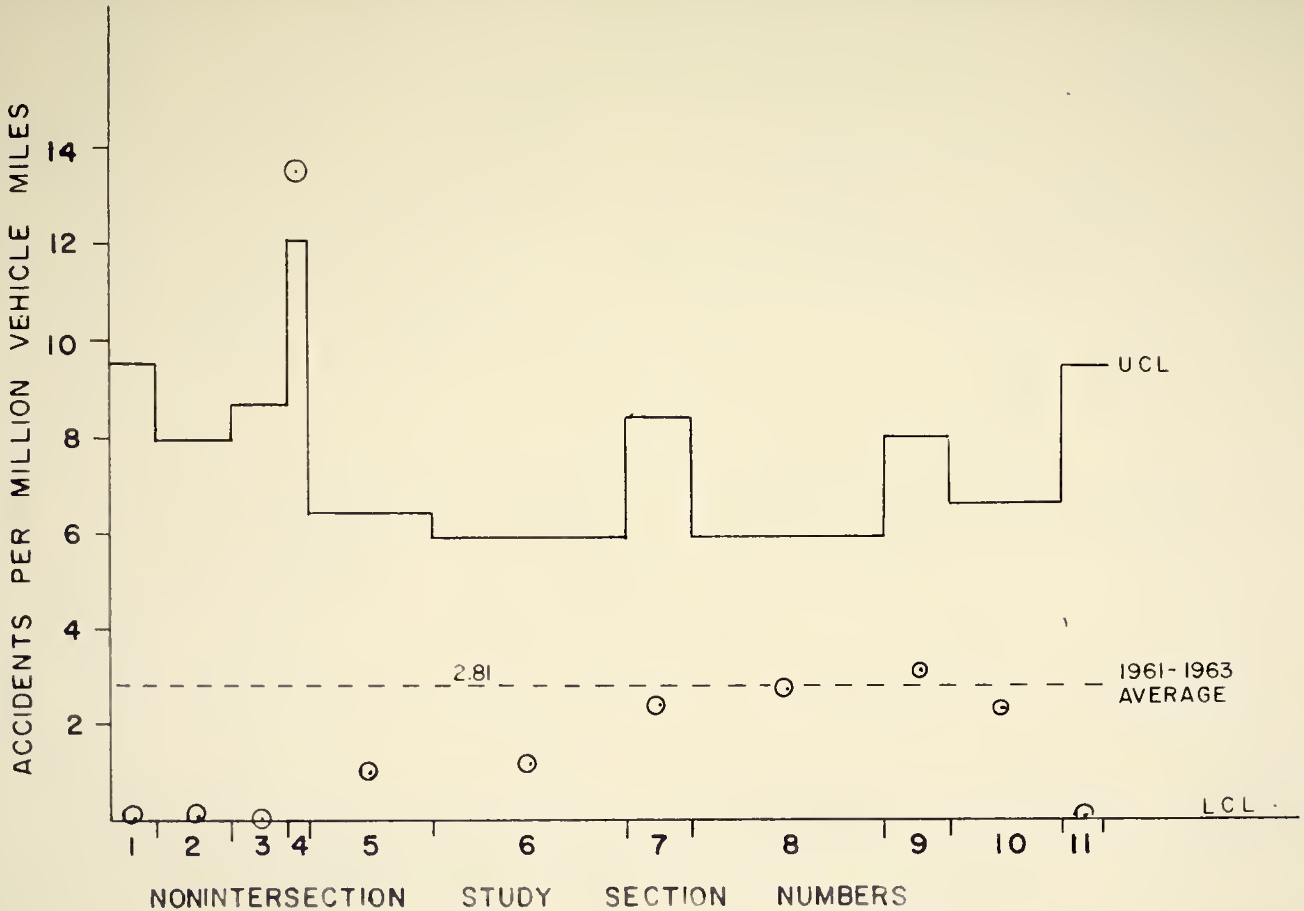


FIGURE 24 QUALITY CONTROL CHART FOR NONINTERSECTION STUDY SECTIONS, 1-11, 1962.

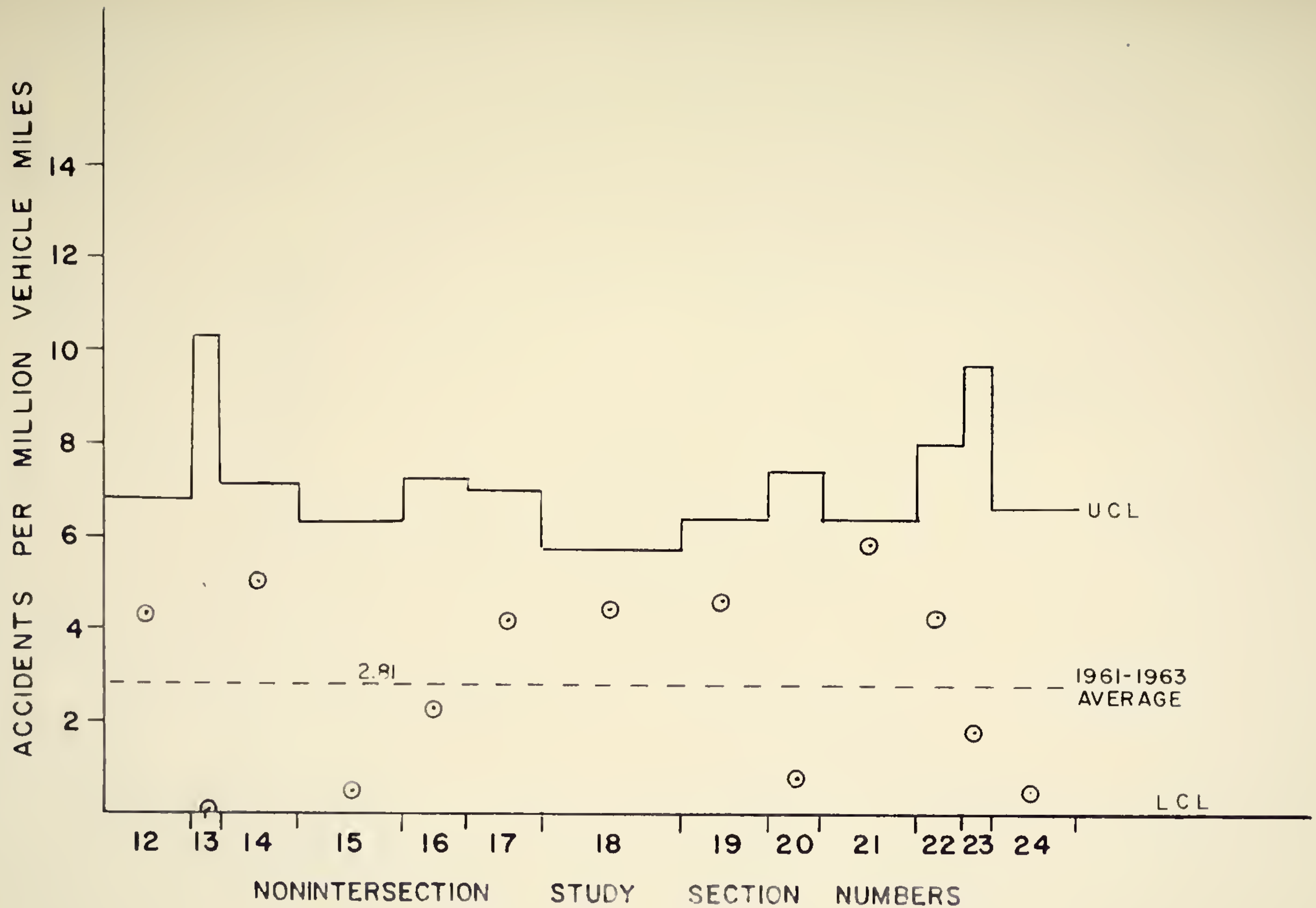


FIGURE 25 QUALITY CONTROL CHART FOR NONINTERSECTION STUDY SECTIONS, 12-24, 1962.

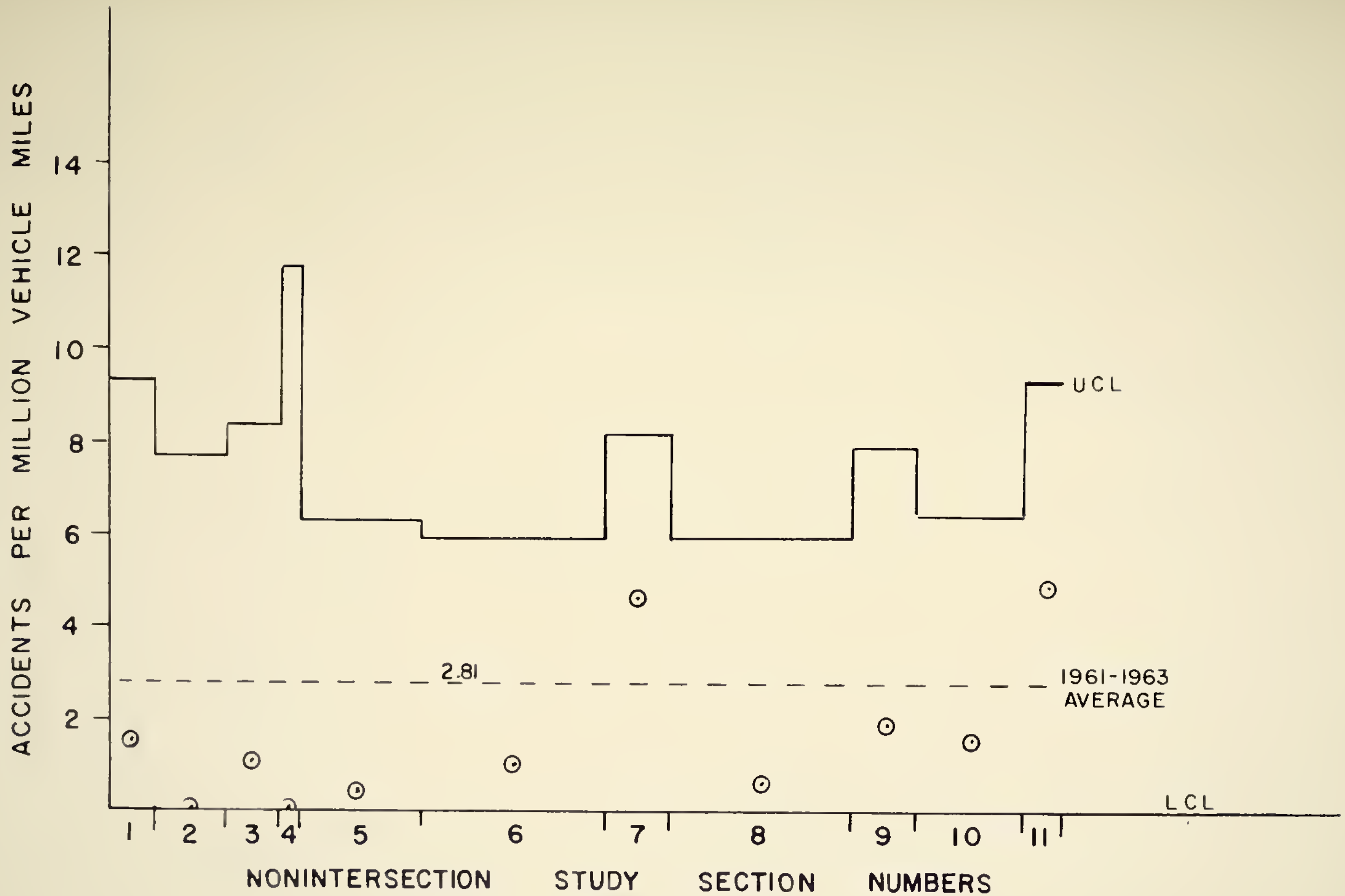


FIGURE 26 QUALITY CONTROL CHART FOR NONINTERSECTION STUDY SECTIONS, 1-11, 1963.

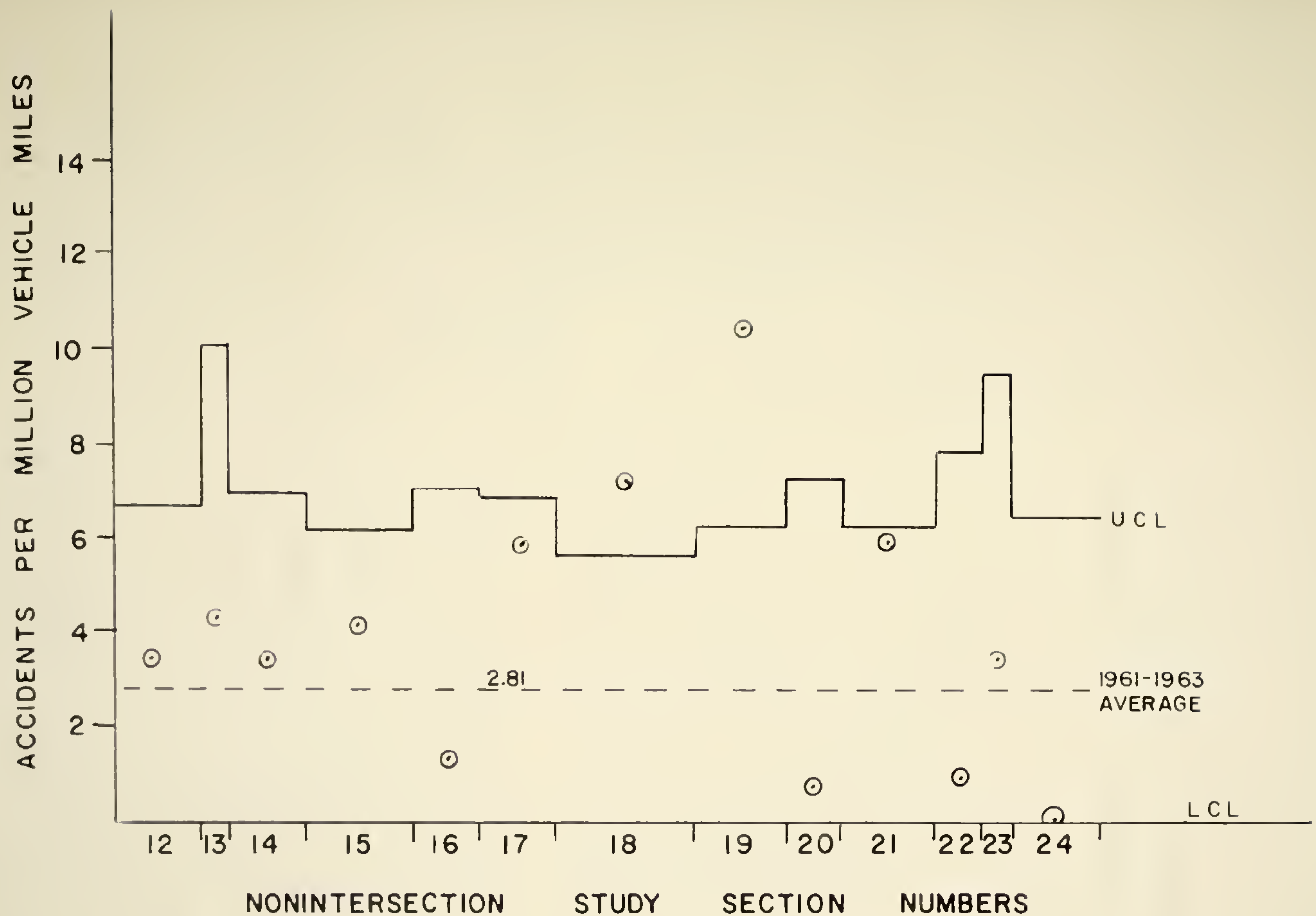


FIGURE 27 QUALITY CONTROL CHART FOR NONINTERSECTION STUDY SECTIONS, 12-24, 1963.

The purpose of this analysis and evaluation was to determine the rate or rates that would indicate best the intersections or sections that were the most or least hazardous and to establish a priority list for traffic engineering improvements.

Accident rates for intersections are analyzed and evaluated below.

1. Number of accidents - This method, the most simple of the accident hazard ratings, was a comparison of the number of accidents at different locations. This is illustrated by an accident spot map for the U. S. 52 By-Pass for 1963 in Figure 28.

   Although the spot map does give an indication of the number of accidents at any given location, it does not include fully the number of vehicles using the intersection. Therefore, it should be restricted to use in comparing intersections of approximately equal volumes. "To compare hazard, accident comparisons must be based on exposure." (7).

   Table 14 shows the ranking of the by-pass intersections by number of accidents. The most hazardous is listed first.

2. Accident rate - Since the number of accidents per million vehicles was highly correlated with intersection ADT (correlation coefficient of 0.610), volume was used as an exposure index in order to provide a more realistic basis for comparing different intersections. This rate was computed in the following manner:

$$\text{Accident rate} = \frac{\text{Number of accidents per Year}}{\text{Number of vehicles going through the intersection per year from all approaches.}}$$

   Accident rates for intersections are expressed as the number of accidents per one million vehicles. (See Figure 29).

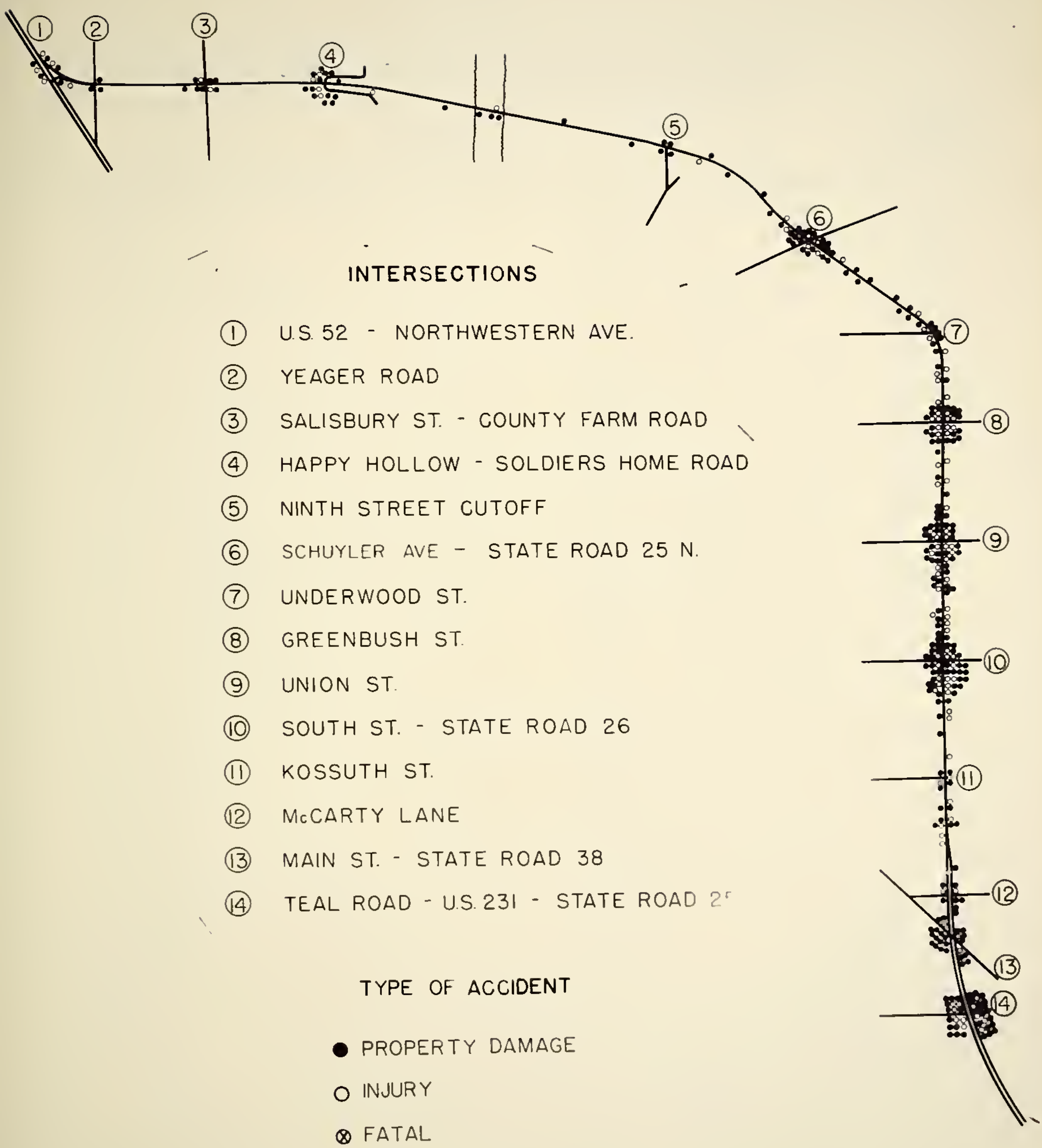


FIGURE 28 1963 ACCIDENT SPOT MAP FOR THE U.S. 52 BY-PASS.

TABLE 14

RANKING OF INTERSECTIONS BY ANNUAL NUMBER OF ACCIDENTS AND ANNUAL NUMBER OF ACCIDENTS PER MILLION VEHICLES.

Rank	Intersection	No. of Accidents	Intersection	Accident Rate
1	Teal Road	27.3	Teal Road	3.33
2	State Road 26	27.0	State Road 26	2.85
3	Union	20.3	State Road 25	2.59
4	State Road 38	20.3	Greenbush	2.47
5	State Road 25	20.0	Union	2.39
6	Greenbush	18.0	State Road 38	2.36
7	Happy Hollow	10.3	Northwestern	1.73
8	Northwestern	8.7	Happy Hollow	1.69
9	Ninth St. Cutoff	8.3	Ninth St. Cutoff	1.53
10	Salisbury	8.0	Salisbury	1.38
11	McCarty	5.3	McCarty	.78
12	Kossuth	5.0	Underwood	.73
13	Underwood	4.7	Kossuth	.73
14	Yeager	1.7	Yeager	.33

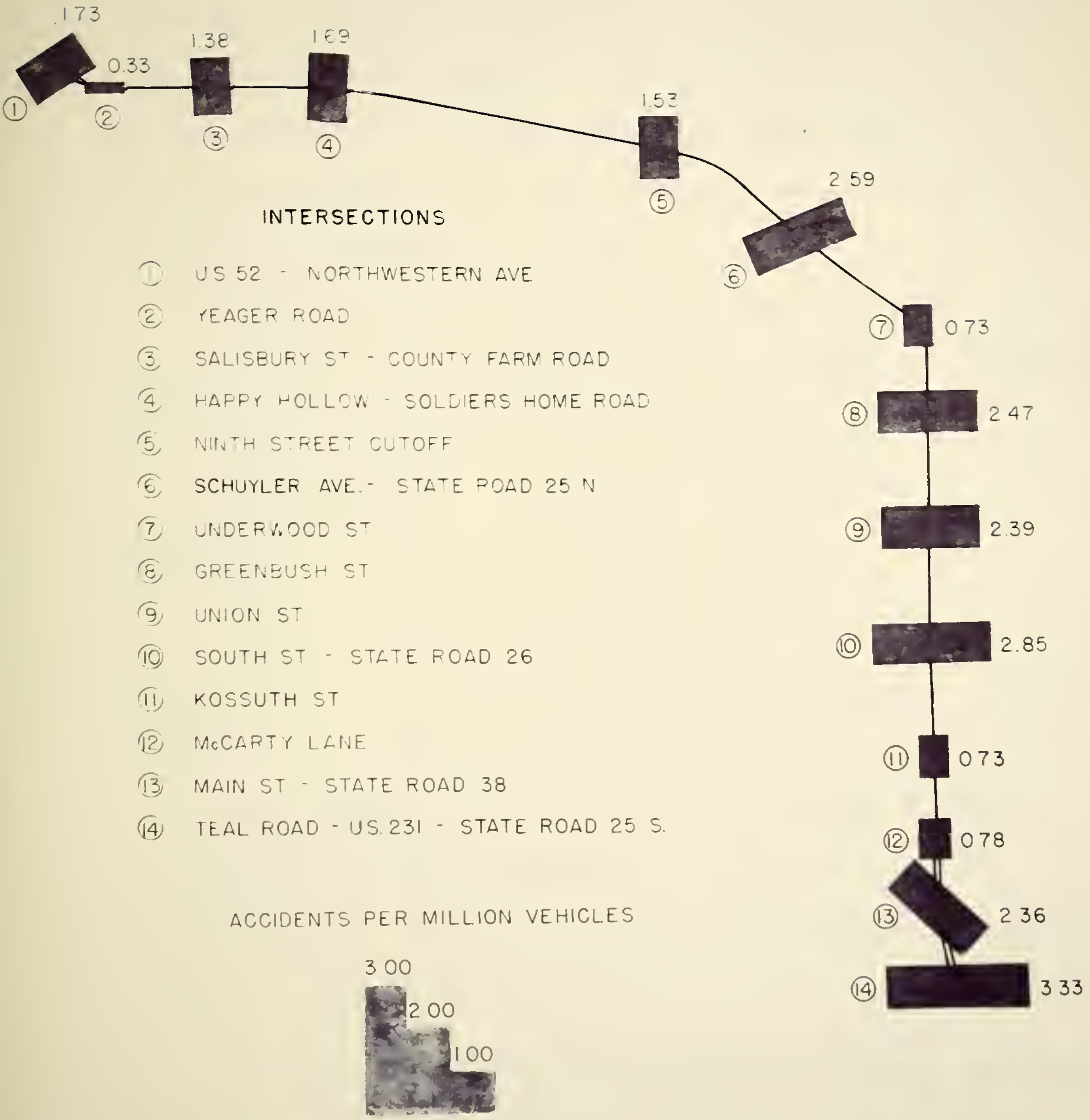


FIGURE 29 AVERAGE ANNUAL INTERSECTION ACCIDENT RATE FOR 1961, 1962 AND 1963.

This method, the most frequently used, includes a measure of exposure. It also indirectly expresses a measure of the severity of accidents since the number of accidents per million vehicles (MV) and the number of injury accidents per MV are highly correlated. (Correlation coefficient is 0.800). Accidents per MV are also intercorrelated with the cost of accidents. (Correlation coefficient is 0.881).

Therefore accidents per MV is a measure of exposure, a measure of severity, and a measure of the total cost of accidents.

	Accidents per MV	Cost	Inj. Acc. per MV
Accidents per MV	1.000	0.881	0.800
Cost	0.881	1.000	0.917
Inj. Acc. per MV	0.800	0.917	1.000

The accidents per MV and the relative rankings of the intersections by this method are also shown in Table 14.

3. Square Theory of Exposure - The following relationship has been used as an alternate accident rate:

$$\text{Accident rate} = \frac{\text{Number of Accidents per year } (10^{12})}{(\text{Number of vehicles going through the intersection per year from all approaches})^2}$$

It was found (see Figure 30) that accidents per million vehicles was correlated with ADT squared (correlation coefficient of 0.634). This was nearly the same as the correlation coefficient of accidents per million vehicles with ADT (0.610).

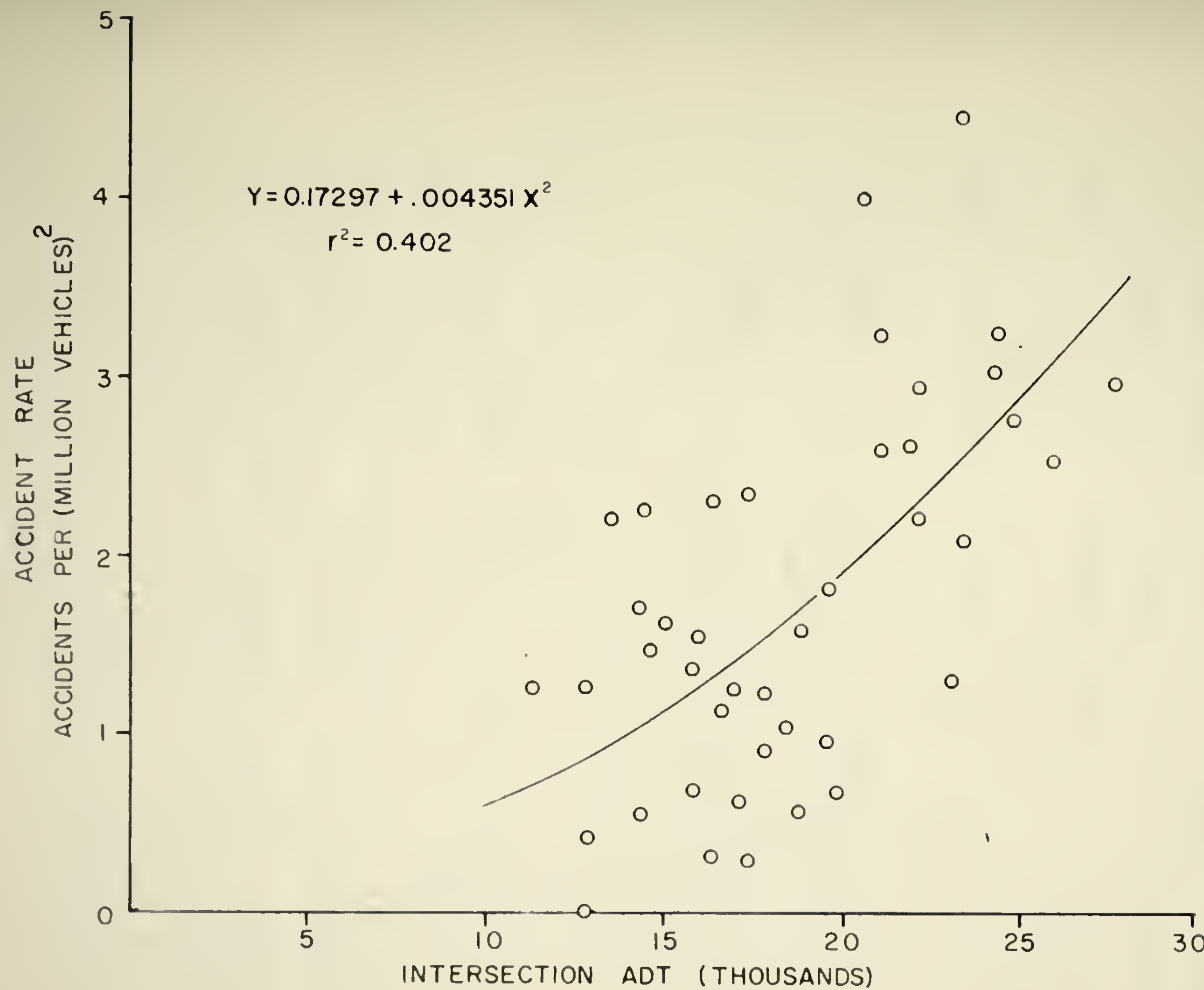


FIGURE 30 RELATION BETWEEN ACCIDENT RATE AND INTERSECTION ADT.

The relative rankings of intersections for this method are shown in Table 15.

4. Measure of Hazard - Another method of comparing intersections was presented by Earl C. Williams (21). Although accidents per million vehicles is the most commonly used accident rate for intersections, it does not consider the capacity of intersections. Because capacity is a function of roadway width and volume these factors were considered by Mr. Williams as suitable measures of the capacity factor.

In general, for a given amount of volume, the wider the pavement the fewer the accidents expected. For two facilities of equal width, the greater the volume, the greater the number of accidents expected. Finally for two facilities of equal width and equal volumes, the facility having more accidents would be the more hazardous facility.

Williams abandoned the idea of using the total entering volume for all approaches. He concurred with McDonald (14) who stated, "No relationship exists between accidents and the sum of the major road and minor road volume." (This study indicated that the simple correlation coefficient between the number of accidents per MV and the sum of the by-pass and cross street volumes was 0.610.)

These considerations led Williams to the following expression for a measure of hazard.

(1) $H_I = \frac{W_1}{V_1} X \frac{W_2}{V_2} X \cdots X \frac{W_n}{V_n} X A_T$

TABLE 15

RANKING OF INTERSECTIONS BY THE SQUARE THEORY OF EXPOSURE AND A MEASURE OF HAZARD

Square theory of Exposure			Measure of Hazard	
Rank	Intersection	Accidents per $(MV)^2$	Intersection	Index of Hazard
1	Teal Road	.433	Teal Road	13,545
2	Greenbush	.359	State Road 38	11,185
3	State Road 25	.352	Salisbury	10,940
4	Northwestern	.347	Happy Hollow	8,932
5	State Road 26	.321	Yeager	5,926
6	Union	.298	State Road 26	5,313
7	State Road 38	.291	State Road 25	5,254
8	Happy Hollow	.289	Union	4,587
9	Salisbury	.289	Greenbush	1,270
10	Ninth St. Cutoff	.257	Underwood	562
11	McCarty	.121	Ninth St. Cutoff	557
12	Underwood	.120	Northwestern	435
13	Kossuth	.112	McCarty	394
14	Yeager	.071	Kossuth	243

Where

H_I = Measure of Intersection Hazard

n = Total number of approaches to the intersection

W_1 = Pavement width available for entering traffic on approach "one" of the intersections

W_2 = Pavement width available for entering traffic on approach "two" of the intersection

W_n = Pavement width available for entering traffic on approach "n" of the intersection

V_1 = Volume (ADT) entering intersection on approach "one"

V_2 = Volume (ADT) entering intersection on approach "two"

V_n = Volume (ADT) entering intersection on approach "n"

A_T = Annual Total of accidents for the intersection

The rankings of the intersections by this method are shown in Table 15.

5. Cost of Accidents - This method consisted of comparing the three year total cost of property damage and injuries for each intersection. The property damage estimates were obtained from the accident reports. Personal injuries were conservatively estimated at $660 each (2). Ten fatalities occurred during the three year study period but were not included in this particular analysis because of the relatively rare occurrence and high value of deaths. Only property damage and personal injury costs were considered in this analysis.

Although this method includes a severity factor, it is not based on an exposure rate.

Table 16 shows the rankings by this method.

6. Cost of Accidents (Rate) - Cost of accidents per million vehicles was another rate used. It provides a measure of the severity of accidents at an intersection, is based on an exposure rate and estimates the economic loss due to traffic accidents. This method could be useful in determining the priority of intersection improvements.

   The rankings are shown in Table 16 for this method.

7. Cost of Accidents (Hazard) - In the expression presented by Williams total costs of property damage and of personal injuries were substituted for the number of accidents.

   Comparing this method with the measure of hazard rating (accident rate number 4), the first (Teal Road), last (Kossuth) and two others (Greenbush and Underwood) stayed the same while the others changed relative positions. (See Table 16).

8. Injuries per intersection - The number of injuries in an accident depends upon the number of persons in the vehicles as well as the type of accident and does not include the exposure characteristic at the intersection.

9. Injury rate - The number of injuries per million vehicles includes an index of exposure.

10. Injury accidents per intersection - This method, similar to accidents per intersection, does not include an exposure index but does eliminate the change factor or number of persons in the vehicles.

TABLE 16

RANKING OF INTERSECTIONS BY COSTS OF ACCIDENTS

Rank	Intersection	Cost (Dollars)	Intersection	Cost per MV (Dollars)	Intersection	Cost of Index of Hazard
1	Teal Road	26,367	Teal Road	3,429	Teal Road	127.3
2	Greenbush	13,673	Northwestern	2,160	Salisbury	91.8
3	Union	13,013	Greenbush	1,987	Happy Hollow	66.0
4	State Road 25	12,930	State Road 25	1,757	State Road 38	49.0
5	State Road 26	12,283	Union	1,623	State Road 25	33.9
6	Northwestern	10,760	State Road 26	1,383	Union	28.2
7	State Road 38	9,303	Happy Hollow	1,368	State Road 26	23.5
8	Happy Hollow	7,987	Salisbury	1,261	Yeager	14.8
9	Salisbury	6,770	State Road 38	1,147	Greenbush	9.4
10	Underwood	4,813	Ninth St. Cutoff	878	Underwood	6.1
11	Ninth St. Cutoff	4,647	Underwood	794	Northwestern	5.4
12	McCarty	4,320	McCarty	670	McCarty	3.2
13	Kossuth	3,003	Kossuth	461	Ninth St. Cutoff	3.2
14	Yeager	423	Yeager	91	Kossuth	1.5

11. Injury accident rate - This rate, injury accidents per million vehicles, includes an exposure index and provides an estimate of the severity of accidents at an intersection. These ratings are shown in Table 17.

In comparing the rankings of the intersections by the number of accidents, the number of accidents per million vehicles and the number of accidents per million vehicles squared, the intersections numbered 6 (S. R. 25), 10 (S. R. 26) and 14 (Teal Road) were consistantly in the top five most hazardous. In the measure of hazard method of these three intersections only Teal Road was ranked in the top five.

In the first three methods, intersections 2 (Yeager), 7 (Underwood), and 11 (Kossuth) and 12 (McCarty) were consistently in the bottom five in the list of intersections. The measure of hazard method included three of these (7, 11 and 12) consistently in the lower five in its ranking of the intersections.

The three methods expressing the costs of accidents at intersections are shown in Table 16. In the first two methods the top six are the same intersections with very little variation and the last five are nearly the same. The cost index of hazard has three of the top six the same as the other two methods and four of the bottom five the same as the other two methods.

Four methods were used to rate injury accidents as shown in Table 17. Intersections 6, 8 and 14 were consistently among the five most hazardous and intersections 2, 5, 7 and 11 were among the five safest intersections. Intersections 5, 7 and 11 are nonsignalized three-approach intersections.

TABLE 17

RANKING OF INTERSECTIONS BY INJURY ACCIDENTS

Rank	Intersection	Injuries per Intersection	Intersection	Injuries per Million Vehicles
1	Teal Road	15.33	Teal Road	1.99
2	State Road 25	7.33	Northwestern	1.34
3	Greenbush	7.00	Greenbush	1.02
4	Northwestern	6.67	State Road 25	1.00
5	Union	5.67	Salisbury	0.87
6	State Road 26	5.00	Happy Hollow	0.74
7	Salisbury	4.67	Union	0.71
8	State Road 38	4.67	State Road 38	0.58
9	Happy Hollow	4.33	State Road 26	0.56
10	Underwood	2.67	Ninth St. Cutoff	0.44
11	Ninth St. Cutoff	2.33	Underwood	0.44
12	McCarty	2.00	McCarty	0.31
13	Kossuth	1.67	Kossuth	0.26
14	Yeager	0.00	Yeager	0.00

Rank	Intersection	Injury Acc. per Intersection	Intersection	Injury Acc. per Million Vehicles
1	Teal Road	8.33	Teal Road	1.08
2	Greenbush	5.00	Greenbush	0.73
3	Union	4.67	Northwestern	0.67
4	State Road 25	4.33	State Road 25	0.59
5	State Road 26	3.67	Salisbury	0.50
6	State Road 38	3.33	State Road 26	0.41
7	Northwestern	3.33	McCarty	0.41
8	Salisbury	2.67	State Road 38	0.41
9	McCarty	2.67	Happy Hollow	0.40
10	Happy Hollow	2.33	Union	0.33
11	Ninth St. Cutoff	1.33	Ninth St. Cutoff	0.25
12	Underwood	1.33	Underwood	0.22
13	Kossuth	1.00	Kossuth	0.15
14	Yeager	0.00	Yeager	0.00

The intersections most often ranked by exposure, cost and severity measures as the most hazardous were 14 (Teal Road), 10 (S. R. 26), 6 (S. R. 25) and 8 (Greenbush) in decreasing order of hazard.

All methods listed Teal Road as the most dangerous intersection on the by-pass.

Those intersections most frequently ranked by exposure, cost and severity measures as the safest intersections were 2 (Yeager), 11 (Kossuth), 7 (Underwood), 12 (McCarty) and 5 (Ninth Street Cutoff) in increasing order of hazard. Nine of the 11 methods listed 2 (Yeager) as the safest intersection on the by-pass.

The accident rate which includes a consideration of exposure and which is highly correlated with the severity and cost of accidents on the by-pass is the number of accidents per million vehicles. This rate was used in comparing intersections in the other parts of this study.

Nonintersection

Twelve different accident rates were used to compare sections of highways in this study. One method, however, was desired for detailed comparison of the sections of highway. Since the ADT volumes ranged from 10,300 to 21,400 vehicles per day and the section lengths varied from 300 to 3,060 feet, it was necessary to choose the method that minimized these variable conditions. The accident rates computed were:

1. Number of accidents - This method is illustrated by the chart in Table 18 and by the accident spot map in Figure 28. The method does not fully consider exposure, but gives the number of accidents on a given length of a highway.

TABLE 18

RANKING OF SECTIONS BY AVERAGE ANNUAL NUMBER OF ACCIDENTS AND SEVERAL MEASURES OF EXPOSURE

Rank	Sect.	No. of Acc.	Sect.	Acc./Mile	Sect.	Acc./10,000 veh.	Sect.	Acc./MVM
1	18	15.0	19	49.9	18	8.46	4	9.30
2	19	13.3	21	35.6	19	7.13	19	6.70
3	21	10.3	18	34.9	21	6.16	21	5.46
4	17	6.3	17	28.7	6	3.90	18	5.01
5	14	5.3	14	23.3	17	3.72	17	4.36
6	12	5.0	12	18.3	8	3.66	14	3.88
7	6	4.7	23	16.3	14	3.44	7	3.60
8	15	4.3	7	16.0	12	3.23	12	3.07
9	8	4.0	4	13.5	10	2.81	23	2.48
10	10	3.7	15	13.2	15	2.60	9	2.45
11	7	3.0	13	13.2	7	2.51	13	2.21
12	4	2.7	9	12.4	4	1.99	10	2.14
13	9	2.3	22	11.4	9	1.78	15	2.09
14	5	2.0	10	10.8	5	1.49	6	1.83
15	16	1.7	11	8.9	22	0.99	1	1.81
16	22	1.7	16	8.3	16	0.98	22	1.77
17	20	1.3	20	8.1	1	0.97	11	1.66
18	23	1.3	6	8.1	3	0.89	8	1.56
19	1	1.0	1	7.1	23	0.79	3	1.37
20	3	1.0	8	6.9	11	0.77	16	1.25
21	11	1.0	3	5.9	20	0.71	20	1.14
22	13	1.0	5	5.4	13	0.65	5	1.06
23	24	0.7	24	1.9	24	0.39	24	0.39
24	2	0.3	2	1.5	2	0.30	2	0.38

2. Accidents per mile - The length of the section is taken into consideration in this method but the volume is not. The ranking of sections by this method is also shown in Table 18.

3. Accidents per 10,000 vehicles - Although volume is considered, the length of the section is not. The results of using this method are shown in Table 18.

4. Accidents per million vehicle miles - This rate is obtained from consideration of the volume as well as the section length. This is the most commonly used expression for accident rates. The sections of this study and their rates are shown in Figure 31. The ranking of the sections by this method is shown in Table 18.

5. Measure of Hazard - This method was suggested by Mr. Earl C. Williams and is similar to his method previously used for intersections (21). The expression used was

$$H_B = \frac{W_B}{V_B} \quad \frac{1}{L_B} \quad A_B$$

Where H_B = Measure of between intersection hazard

W_B = Total pavement width (feet) of the roadway between intersecting streets

V_B = Total volume (two directions) ADT

L_B = Total length of block in feet

A_B = Annual total of accidents in area between intersections

This expression provides a measure of the hazard on a section. It includes an estimate of the volume (V_B), the capacity (W_B) and the length of the section (L_B). The ranking of the sections by this method is shown in Table 19.

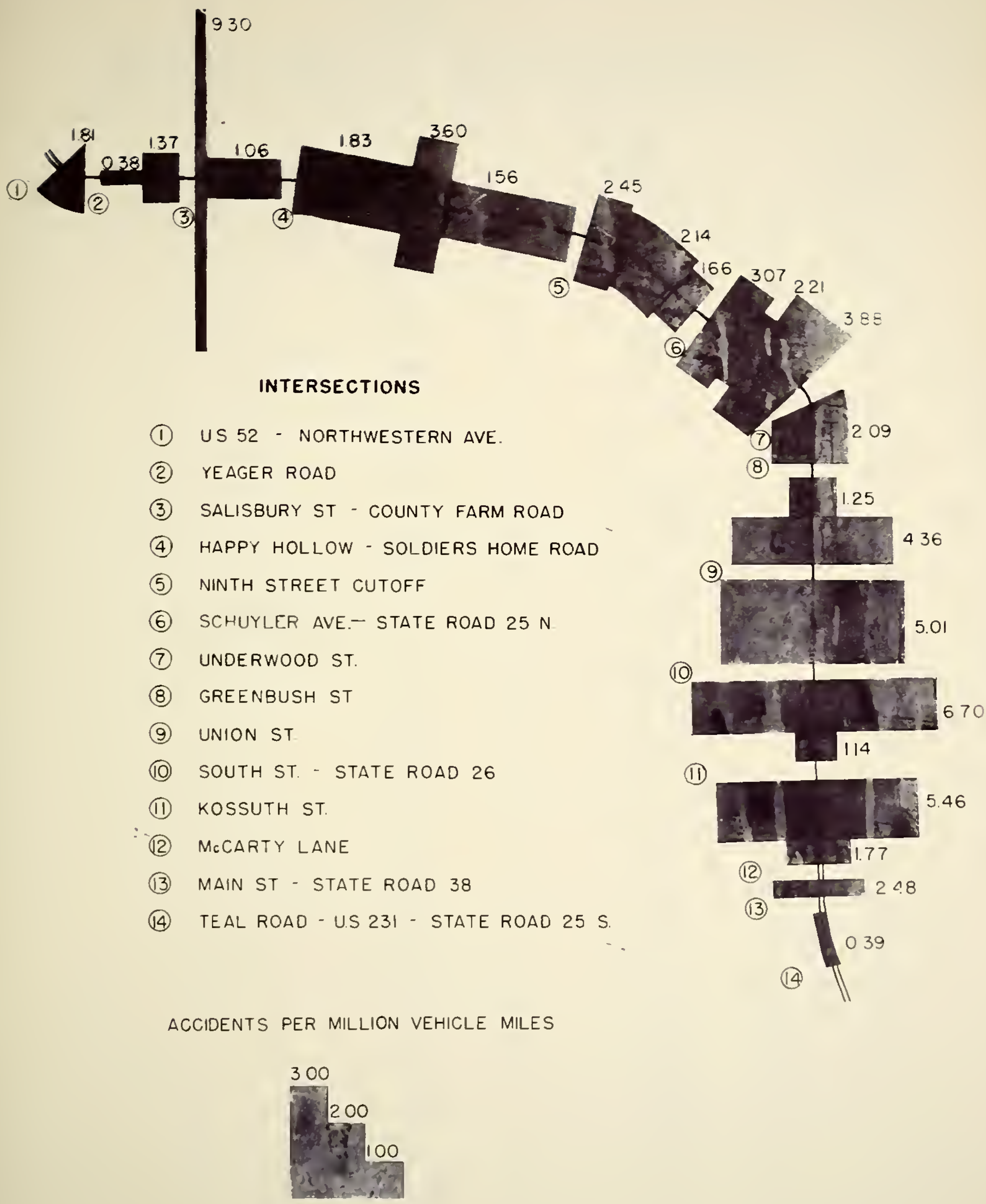


FIGURE 31 **AVERAGE NONINTERSECTION ACCIDENT RATES ON THE U.S. 52 BY-PASS FOR 1961, 1962 AND 1963.**

TABLE 19

RANKING OF SECTIONS BY A MEASURE OF HAZARD AND SEVERAL MEASURES OF AVERAGE ANNUAL COSTS OF ACCIDENTS

Rank	Sect.	Hazard (100)	Sect.	Cost (Dollars)	Sect.	$\frac{\text{Cost}}{\text{MVM}}$ (Dollars)	Sect.	$\frac{\text{Cost}}{\text{Hazard}}$ (1000)
1	4	141	19	12,723	4	12,679	4	199
2	19	102	18	10,332	19	6,531	19	98
3	21	84	21	7,300	17	4,441	17	67
4	18	76	15	6,407	21	3,883	15	61
5	23	76	17	6,373	14	3,877	14	59
6	17	67	14	5,323	7	3,747	21	58
7	14	59	6	5,253	18	3,513	7	57
8	7	55	8	5,203	15	3,139	18	53
9	12	47	4	3,753	11	2,268	6	47
10	6	42	12	3,280	6	2,049	22	39
11	15	42	7	3,110	12	2,033	11	35
12	22	41	10	2,460	8	2,021	8	31
13	9	37	5	2,073	1	1,881	12	31
14	13	34	9	1,870	13	1,758	9	29
15	10	33	11	1,363	10	1,427	1	27
16	1	28	20	1,246	23	1,291	13	27
17	11	25	1	1,063	9	1,085	10	25
18	8	24	16	860	5	1,078	5	17
19	20	22	13	786	20	1,047	20	16
20	3	21	23	683	16	656	23	12
21	16	19	22	487	22	523	16	10
22	5	16	24	466	3	520	3	8
23	24	12	3	400	24	266	24	8
24	2	6	2	43	2	49	2	1

6. Costs of accidents - This method reflects the property damage and injury costs of accidents on each of the sections. It is a measure of the severity of accidents but does not consider the varying lengths and volumes of the sections. The ranking of sections by this method is shown in Table 19.
7. Costs of accidents per million vehicle miles - This is a measure of the severity, volume, and length of the section. The ranking of the sections by this method is also shown in Table 19.
8. Cost hazard - In this method the costs of property damage and injury accidents were substituted for the number of accidents in the formula by Williams. The ranking of the sections by this method is shown in Table 19.
9. Number of injuries per section - This is a measure of the severity of accidents on a section of highway. It includes no measure of the volume or length of the section. The ranking of the sections is shown in Table 20.
10. Number of injuries per million vehicle miles - This method indicates the severity of accidents and reflects the volume and the length of a section. Table 20 also shows the ranking of the sections by this method.
11. Number of injury accidents per section - Because the number of injuries in an accident is a function of the number of persons in the car, this method might provide a better measure of the severity of accidents on a section of highway. The method, however, does not include a measure of the volume or the length of the section. The ranking of sections by this method is illustrated in Table 20.

TABLE 20

RANKING OF SECTIONS FOR INJURY ACCIDENTS
BY SEVERAL RATES

Rank	Sect.	No. of Injuries	Sect.	No. of Injuries / MVM	Sect.	No. of Injury Accidents	Sect.	Injury Accidents / MVM
1	19	9.3	4	7.883	19	6.3	4	6.757
2	18	7.7	19	4.791	18	5.7	19	3.252
3	17	4.7	17	3.252	17	2.7	20	2.807
4	15	4.0	18	2.606	15	2.3	16	2.550
5	21	4.0	14	2.424	21	2.3	18	1.927
6	14	3.3	7	2.409	4	2.0	17	1.859
7	8	2.7	21	2.128	8	2.0	12	1.628
8	4	2.3	15	1.960	12	1.7	7	1.607
9	6	2.3	1	1.766	7	1.3	21	1.241
10	7	2.0	23	1.260	14	1.3	15	1.144
11	12	1.7	11	1.109	6	1.0	11	1.110
12	5	1.3	9	1.050	5	0.7	14	0.972
13	1	1.0	8	1.036	9	0.7	8	0.777
14	9	1.0	12	1.033	10	0.7	13	0.747
15	10	1.0	6	0.910	11	0.7	9	0.701
16	11	0.7	13	0.746	1	0.3	23	0.631
17	23	0.7	5	0.693	13	0.3	1	0.588
18	13	0.3	10	0.647	16	0.3	6	0.390
19	16	0.3	20	0.280	20	0.3	10	0.387
20	20	0.3	16	0.254	23	0.3	5	0.347
21	2	0.0	2	0.000	2	0.0	2	0.000
22	3	0.0	3	0.000	3	0.0	3	0.000
23	22	0.0	22	0.000	22	0.0	22	0.000
24	24	0.0	24	0.000	24	0.0	24	0.000

12. Number of injury accidents per million vehicle miles - This method provides an estimate of the severity of accidents on a section of highway and includes the volume and the length of the section. Table 20 also provides the ranking of the section of this study using this method.

In the four methods of accident rates shown in Table 18 , sections numbered 12, 14, 17, 18, 19 and 21 were consistently in the upper third of the section rankings. Sections numbered 2, 3 and 24 were consistently in the lower third of the ratings.

In comparing the accidents per million vehicle miles and the hazard method, the first nine sections are the same with very little change in their order and the last eight sections are the same with very little variation.

In comparing the three methods of costs of accidents in Table 19, sections numbered 14, 15, 17, 18, 19 and 21 were consistently in the top third. The least costly sections were those numbered 2, 3, 16 and 24.

Those sections which ranked in the upper third of the injury rate comparisons in Table 20 were numbers 4, 17, 18 and 19. Those sections consistently in the lower third were numbers 2, 3, 22 and 24.

Simple correlation coefficients among three dependent variables, accidents per million vehicle miles (Y_{29}), accident cost (Y_{30}) and injury accidents per million vehicle miles (Y_{31}) are shown below.

Simple Correlation Coefficients

	Y_{29}	Y_{30}	Y_{31}
Y_{29}	1.000	0.601	0.828
Y_{30}	0.601	1.000	0.491
Y_{31}	0.828	0.491	1.000

Accidents per millions vehicle miles (Y_{29}) was highly correlated with accident cost (Y_{30}) and injury accidents per million vehicle miles (Y_{31}). Accidents per million vehicle miles and the measure of hazard were also found to give nearly the same results in the ranking of the sections. In addition, accidents per million vehicle miles is the most frequently used expression of accident rate. Therefore, the rate used in the other portions of this study was accidents per million vehicle miles.

Collision-Condition Diagrams

Each intersection was analyzed for each of the three years by using the collision-condition diagrams shown in Appendix C . The results of this analysis are listed below by number and intersecting street:

Intersections

1. Northwestern Ave.

   The left-turn movement for traffic northbound on the by-pass is an extremely hazardous one. Drivers making this movement are probably looking to the left for approaching traffic and may not see the stop sign on the right. A sign on this approach indicates that northbound traffic should keep right and double yellow lines attempt to encourage this measure. This, however, may discourage left turning traffic from getting into the left lane until they must make the turning movement.

2. Yeager Road.

This is the safest intersection on the by-pass. Extra lanes have been added to the north side of this intersection since this study period terminated.

3. Salisbury Street.

A traffic signal was installed here in May 1962. The following accidents took place before and after installation of the traffic signal.

Types of Accidents Before and After Signal Installation

	Before	After	Ratio $(\frac{\text{After}}{\text{Before}})$
Injuries	4	10	2.2
Rear-end	2	8	3.6
Right angle	5	4	0.7
Total accidents	10	14	1.3
Time in months	17	19	1.0

The traffic signal is semi-actuated on the cross street. About one-half of the accidents involving east bound traffic since the signal has been installed have been rear-end accidents.

4. Happy Hollow Road.

There were 14 right angle and ten rear-end collisions. Twenty-three of the 31 accidents involved west bound traffic nearing the crest of a steep hill. The sight distance is very poor for these drivers as well as to the east for the drivers on the cross street. The fastest moving west bound cars are also in the same lane as left-turning vehicles because of a slow traffic lane on the right.

5. Ninth Street Cutoff.

In September, 1962 extra approach and recovery lanes were added on the by-pass at this location (see Ninth Street Cutoff, Appendix C). The following accidents occurred before and after the construction of these lanes.

Types of Accidents Before and After the Construction of Approach and Recovery Lanes

	Before	After	Ratio $\left(\frac{\text{After}}{\text{Before}}\right)$
Rear-end	4	1	0.3
Right angle	6	1	0.2
Left turn	13	3	0.3
Injuries	6	1	0.2
Total accidents	18	7	0.5
Time in months	20	16	1.0

There is a sign warning of left-turning vehicles ahead for the west bound by-pass traffic.

In 1963 after the additional lanes were constructed, only Yeager Road had a lower accident rate.

6. S. R. 25 North.

This is the third most hazardous intersection. Nearly one-third (18 accidents) of the accidents resulted from improper lane usage. These accidents often resulted from vehicles trying to change traffic lanes at the last minute. Ten of these accidents happened in approach lanes and eight in exit lanes. There were nine right angle collisions indicating some involved vehicles possibly were going through on the red. Of the 13 rear-end collisions on the by-pass approaches, nine involved southeast bound vehicles. In the three-year study period, vehicles turning left from the by-pass were involved in only two accidents, both occurring in 1961.

7. Underwood Street.

All of the 14 accidents in the three years involved left-turning vehicles. Thirteen accidents involved north bound vehicles.

8. Greenbush Street.

As indicated in the quality control and accident rate analysis, the accident rate for 1963 was more than twice that of either 1961 or 1962.

A comparison of the types of accidents for each year is shown below. All types of accidents increased in 1963 over 1962 or 1961.

Types of Accidents at Greenbush Street

	1961	1962	1963
Total accidents	11	13	30
Injury accidents	2	2	11
Right angle	1	4	7
Left turn	1	3	4
Rear-end	8	7	12
Lane change	0	1	7
South bound vehicles	11	12	29
North bound vehicles	9	11	19
East bound vehicles	1	4	4
West bound vehicles	0	0	3

No apparent reason could be found for the large 1963 increase.

9. Union Street.

As illustrated in the quality control charts, the accident rate for Union Street in 1962 was about one-half that of 1961 or 1963.

The types of accidents are summarized below for the three years.

Types of Accidents at Union Street

	1961	1962	1963
Total accidents	21	11	29
Injury accidents	3	2	9
Right angle	2	2	3
Left turn	4	1	4
Rear-end	11	8	18
Lane change	4	5	9
North bound vehicles	28	13	30
South bound vehicles	12	7	20
East bound vehicles	1	1	4
West bound vehicles	1	1	4

No apparent cause for the decrease of accidents in 1962 could be found.

10. State Road 26.

This is the second most hazardous intersection and has the highest intersection ADT.

The types of accidents are summarized below.

Types of Accidents at State Road 26

	1961	1962	1963
Total accidents	27	24	30
Injury accidents	2	3	6
Right angle	2	0	2
Left turn	6	8	10
Rear-end	18	16	15
Lane change	2	2	5
North bound vehicles	21	10	18
South bound vehicles	20	25	29
East bound vehicles	4	7	4
West bound vehicles	8	6	4

At this intersection south bound vehicles had more accidents than north bound traffic. The opposite is true for the by-pass as a whole.

11. Kossuth Street.

Ten of the 15 accidents involved left turning vehicles. Seven of these ten involved north bound traffic.

12. McCarty Lane.

Four accidents were right angle collisions while six others involved south bound vehicles changing lanes.

13. State Road 38.

In January 1963 a flasher at this intersection was changed to a traffic signal.

Listed below are the types of accidents that happened before and after the traffic signal was installed.

Types of Accidents at State Road 38
Before and After Signal Installation

	Before	After	Ratio $(\frac{\text{After}}{\text{Before}})$
Total accidents	26	25	1.4
Time in months	24	12	1.0
Injury accidents	7	3	0.9
Right angle	26	6	0.5
Left turn	10	4	0.8
Rear-end	6	13	4.3
Lane change	2	2	2.0
North bound vehicles	19	21	2.2
South bound vehicles	18	17	1.9
East bound vehicles	17	4	0.5
West bound vehicles	16	8	1.0

The annual number of right angle collisions was one-half of the annual number before the signal change. Rear-end collisions increased by a factor of four. The number of by-pass vehicles in accidents more than doubled after the change while the number of vehicles in accidents on the cross streets decreased by 25 percent.

14. Teal Road (U. S. 231).

All variations of intersection accident rates used in this study indicated that this was the most hazardous of the by-pass intersections. Quality control charts illustrated that this intersection was out of control each of the three years.

The different types of accidents that occurred prior to the installation of the traffic signal in January 1963 and after this change are shown below.

Types of Accidents Before and After Traffic Signal Installation

	Before	After	Ratio $(\frac{\text{After}}{\text{Before}})$
Total accidents	44	38	1.7
Time in months	24	12	1.0
Injury accidents	10	15	3.0
Right angle	29	15	1.0
Left turn	10	4	0.8
Rear-end	4	17	8.5
Lane change	1	4	8.0
North bound vehicles	16	34	4.3
South bound vehicles	21	27	2.6
East bound vehicles	32	17	1.1
West bound vehicles	*	8	-

*No west bound approach prior to signal.

All types of accidents increased with one exception, left-turn accidents. Left-turn lanes were constructed on the by-pass when the signal was installed.

Nonintersections

Each nonintersection accident was analyzed by use of the collision diagrams drawn from the investigating officer's report. A summary of this analysis is shown in Table 21. This table presents the sections most

TABLE 21

TYPES OF ACCIDENTS ON THE MOST HAZARDOUS NONINTERSECTION STUDY SECTIONS

	Section Number											
	4	7	10	12	14	15	17	18	19	21	Total	% of these acc.
Accident Rate	9.30	3.60	2.14	3.07	3.88	2.09	4.36	5.01	6.60	5.46	4.29	--
No. of Acc.	8	9	11	15	16	13	19	45	40	31	207	--
Injuries	7	6	3	5	10	12	14	18	28	12	115	--
Pavement wet or icy	4	6	6	6	5	6	3	12	16	18	82	40
Type I	0	0	1	1	0	2	6	15	9	2	36	18
Type II	7	1	2	5	8	7	8	23	26	21	108	52
Type III	1	3	4	3	7	1	2	2	3	1	27	13
Type IV	0	5	4	6	1	3	3	5	2	7	36	17
7 - 8 AM 2 - 8 PM	6	4	3	6	12	6	14	31	25	19	126	61
Night	1	3	7	6	1	0	1	4	4	6	33	16

frequently rated as the most hazardous. These ten sections had 74 percent of the nonintersection accidents.

Section 4 had a large percentage of injury accidents. Seven of the eight accidents were Type II or marginal accidents and six of the eight accidents occurred during a high-volume hour of the day.

On section 7, the Wabash River Bridge, six of the nine accidents occurred when the pavement was wet or icy.

Seven of the eleven accidents on section 10 happened at night. Six of the total accidents were on wet or icy pavement.

On section 12, six accidents happened during the peak hours and six occurred at night. One-half the accidents on section 14 involved vehicles trying to enter the traffic stream at an access point. Three-fourths of the accidents occurred during the peak hours. Section 15 had a high percentage of injury accidents.

One half of the nonintersection accidents occurred on sections 17 thru 21. On this 1.6 miles of highway, 58 percent of the accidents involved marginal friction, two-thirds of the accidents occurred during the peak hours, and 35 percent of the accidents occurred when the pavement was wet or icy.

Other Analyses

Hour of Day

As shown in Figure 32, the following hours had accident rates above 6.87 accidents per million vehicle miles, the three-year-average accident rate for the by-pass:

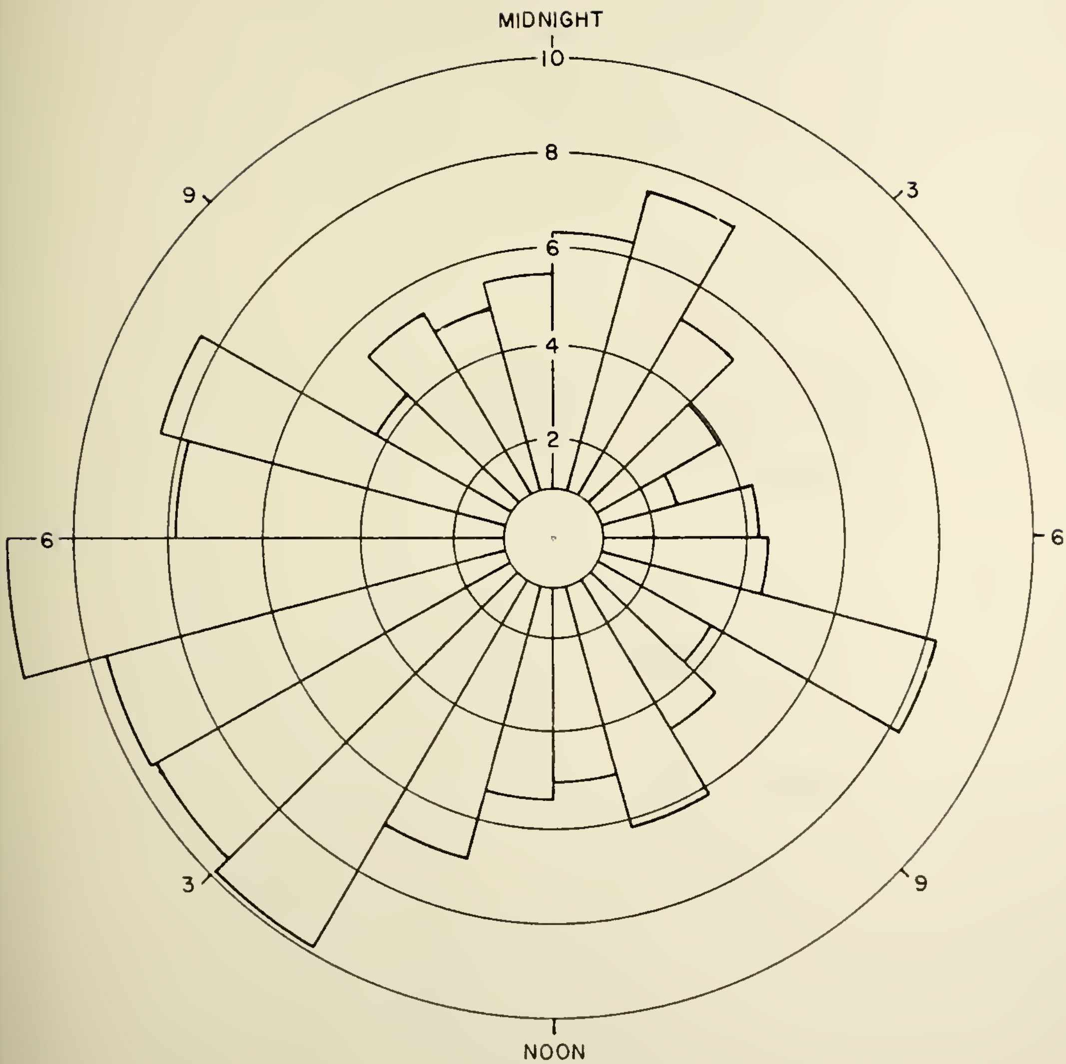


FIGURE 32 AVERAGE ANNUAL ACCIDENTS PER MILLION VEHICLE MILES BY HOUR OF DAY FOR 1961, 1962 AND 1963.

Hour	Accident Rate
1-2 A.M.	7.5
7-8 A.M.	8.2
1-2 P.M.	6.9
2-3 P.M.	9.8
3-4 P.M.	9.5
4-5 P.M.	9.6
5-6 P.M.	11.4
6-7 P.M.	7.8
7-8 P.M.	8.3

These hours represented 37.5 percent of the day but had 62.5 percent of the daily accidents, 59 percent of the injuries and 50 percent of the fatalities.

According to Accident Facts, 1964, (1) "During the first few hours after midnight, fatal motor-vehicle accidents reach a peak rate nearly ten times higher than the low rate for the day which occurs during the late morning hours." This peak, although somewhat smaller, was also experienced in this study for accident rates rather than death rates. Those driving during this hour are undoubtedly more tired and less alert than the day-light driver. Approximately 37 percent of the accidents that happened during this hour were single-car accidents.

The hour beginning at 7:00 A.M. represents the morning rush hour and the hour beginning at 5:00 P.M. is the evening peak hour.

Above average accident rates are shown from 1:00 P.M. until 8:00 P.M. with the highest rates from 2:00 P.M. until 6:00 P.M. During this period a large percentage of the traffic is probably local while a substantial number of through-trip drivers are also trying to reach their destinations in Chicago or Indianapolis before evening. Through-trip drivers probably provide flow characteristics that are different from the local drivers. A high volume of these through and local drivers operating under traffic congestion conditions, undoubtedly create a high accident potential.

Day of Week

Monday, Tuesday, Wednesday and Thursday had nearly the same accident rates. (See Figure 33). Friday and Saturday accident rates were about one and one-half (1-1/2) that of the weekday average and Sunday accident rates were nearly twice the weekday average. Sunday also had more accidents but fewer vehicle miles driven than any other day of the week. The "Sunday driver" apparently is at his worst on this facility. One reason for this increase in accidents on Sundays might again be due to the difference in flow characteristics. Some drivers are pleasure riding with their families and are in no hurry while other drivers are making inter-city trips and would like to by-pass the cities as soon as possible. The differences in speeds and the alertness of these drivers to other vehicles probably account for many accidents.

Month of Year

At first glance accident rates vs. the months of the year (see Figure 34) appear to follow no pattern unless it might be one month with a high accident rate followed by a month with a low accident rate. However, further examination showed that the seven months with 31 days are those with the highest accident rates while the four months with 30 days are the months with the lowest accident rates. February, with 28 days, was

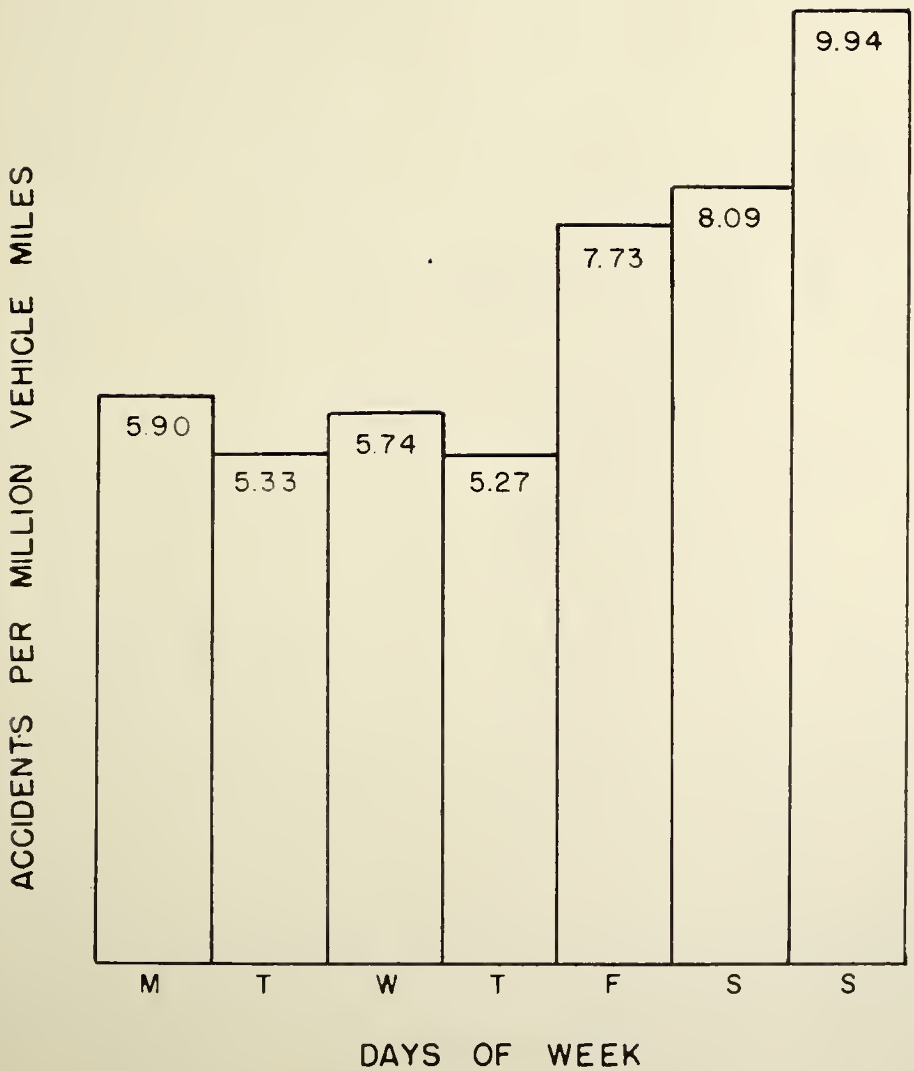


FIGURE 33 AVERAGE ACCIDENT RATES BY DAY OF THE WEEK FOR 1961, 1962 AND 1963

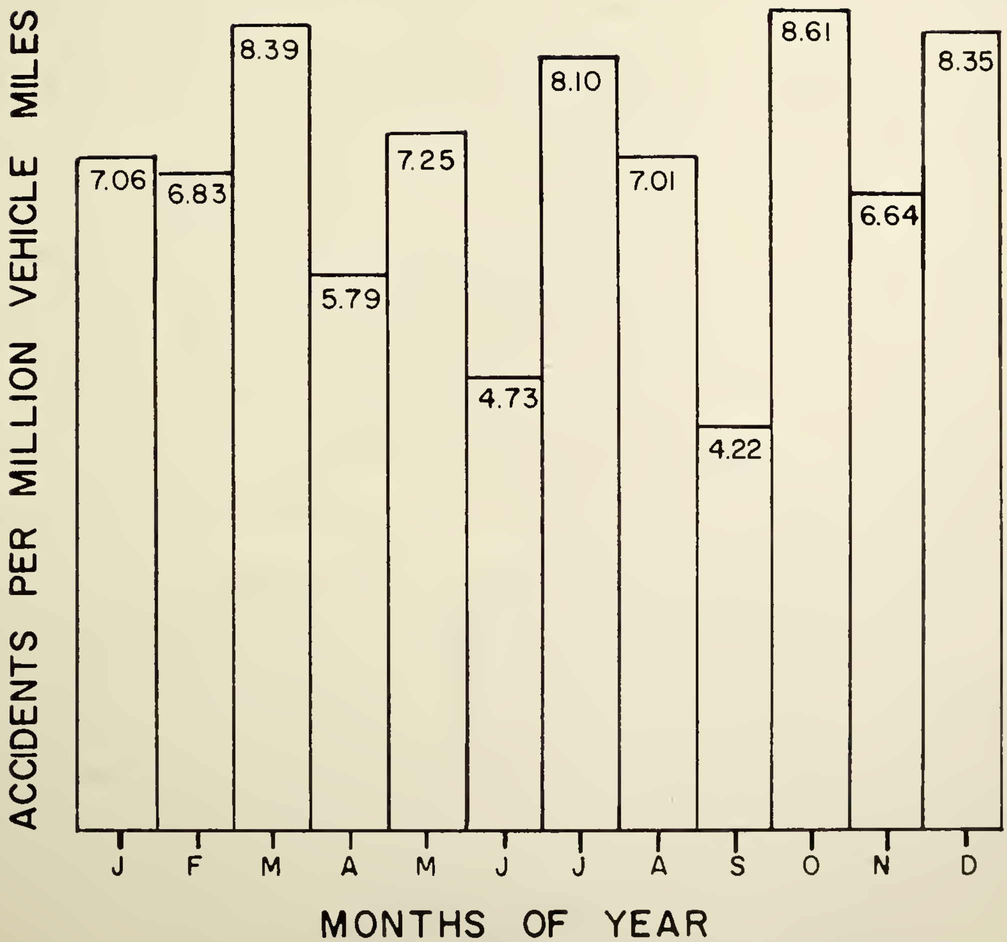


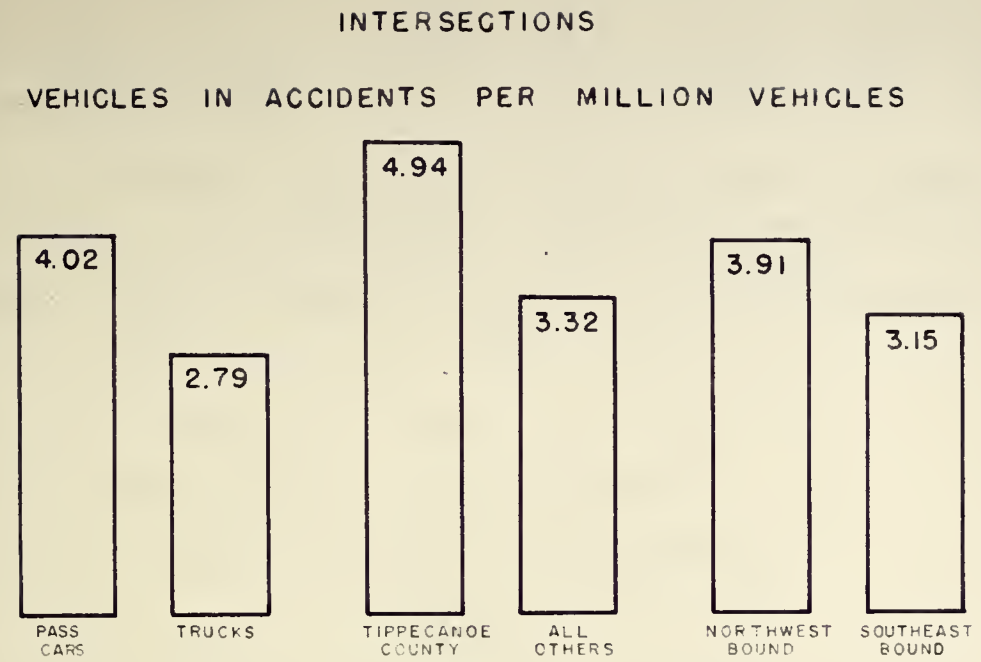
FIGURE 34 AVERAGE ACCIDENT RATES BY MONTHS OF YEAR FOR 1961, 1962 AND 1963

in between these two groups. Since the accident rate, containing volume as a factor, already takes into account that one group had more days and since the difference in accident rates was too great for the difference in the number of days involved (31-day-month average accident rate was 7.8 while the 30-day-month average was 5.3), it was decided that this particular relationship (the number of days in the month) was coincidental. However, another analysis proved to be more significant.

Four of the major holidays, Memorial Day, Fourth of July, Christmas and New Years Day, are in these high accident months. These months also have an average of 3.0 inches of precipitation per month while the others have 2.3 inches per month. March was second only to July for the amount of precipitation per month. Rainfall is later shown to be correlated with accident rates. Saturdays in October with Purdue home football games had nearly three times the number of accidents as the average number of accidents for Saturdays. Memorial Day not only brings the regular holiday traffic through the by-pass but the Indianapolis 500 traffic completely congests the by-pass for several hours. July and August have the highest ADT's of all months. November with Thanksgiving has the highest accident rate of the 30-day-month group. In general, then, high volumes with a large percentage of through traffic, and inclement weather, or both factors appear to account for at least a part of the high accident rates in certain months.

Involvement Rates

Passenger cars had a higher involvement rate than trucks as shown in Figure 35. Tippecanoe County vehicles had a higher involvement rate per



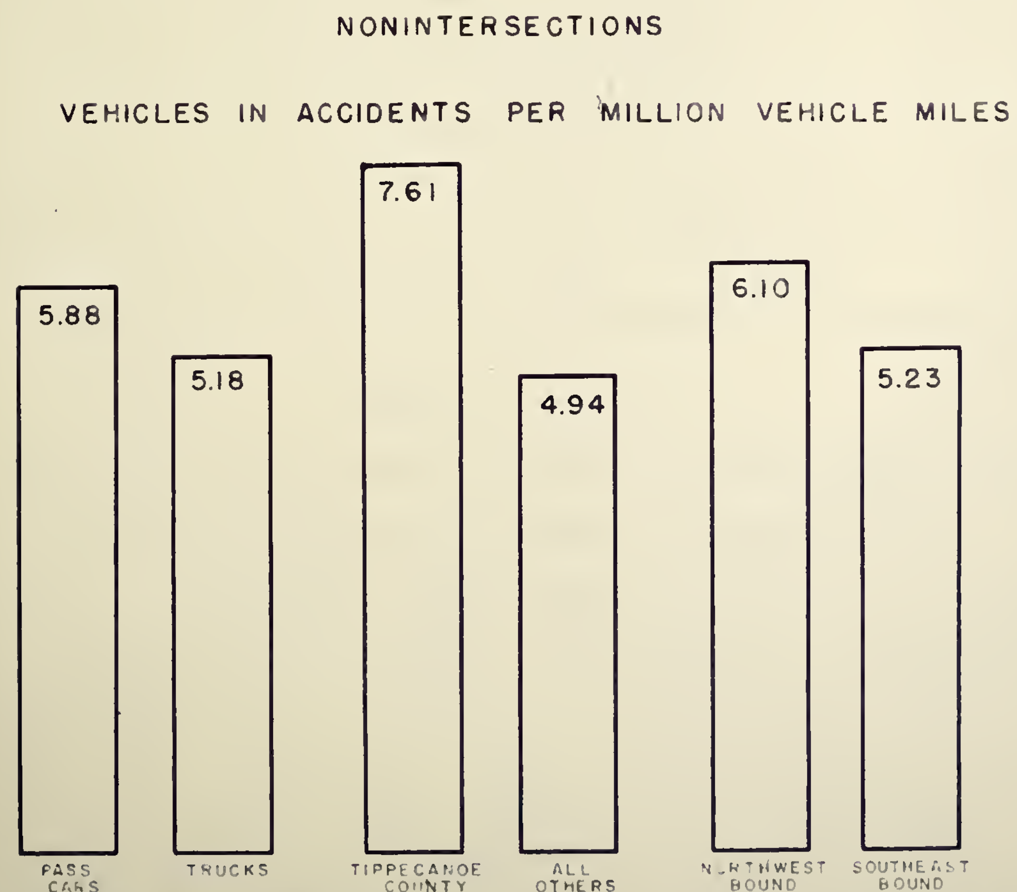


FIGURE 35 INVOLVEMENT RATES FOR VEHICLES BY TYPE, REGISTRATION AND DIRECTION FOR 1961, 1962 AND 1963.

million vehicle miles and per million vehicles for nonintersection study sections and intersections respectively than all other vehicles. Northwest bound vehicles also had a higher involvement rate than southeast bound vehicles. Most of the commercial development as well as the total development of the two cities is on the left side of the by-pass for northwest bound traffic. Since the left-turn accident was found to occur four times more frequently than the right-turn accident the direction of travel that had the most left-turns was the most hazardous. These comparisons were true for intersection as well as the nonintersection study sections.

Weather

Precipitation data (20) by hour and by month are shown in Tables 22 and 23. These data were used to determine accident rates for clear or rainy and snowy weather. The comparative rates are shown in Figure 36. With these extreme differences in rates it appeared obvious that the occurrence of precipitation and the accident rate must be correlated. This correlation was investigated and is discussed in a following section.

Severity

The ratio of fatal accidents to injury, to property damage, and to total accidents is approximately 1:25:85:111 for intersections and 1:17:38:56 for nonintersection study sections (see Figure 37). The overall ratio for the by-pass was 1:21:61:83. The same ratio for Indiana in 1963 was 1:33:97:131.

Time Variations

A weekend was defined as starting at 6:00 P.M. on Friday and terminating at 6:00 A.M. Monday. The weekend vs. weekday accident rates are

TABLE 22

FREQUENCY OF PRECIPITATION BY HOUR OF DAY
FOR A TEN-YEAR PERIOD, 1954-1963

Hour	Number of times precipitation fell during this hour in a ten year period
12 AM - 1 AM	57
1 - 2	61
2 - 3	64
3 - 4	64
4 - 5	66
5 - 6	66
6 - 7	65
7 - 8	68
8 - 9	67
9 - 10	67
10 - 11	63
11 - 12	64
12 - 1 PM	62
1 - 2	64
2 - 3	66
3 - 4	66
4 - 5	65
5 - 6	62
6 - 7	61
7 - 8	63
8 - 9	65
9 - 10	64
10 - 11	65
11 - 12	61
	1536

$$\text{Average} = \frac{1536}{24} = 64$$

$$\text{Percent of time precipitation fell} = \frac{6.4 \times 24 \times 100}{365 \times 24} = 1.75\%$$

TABLE 23

NUMBER OF DAYS PRECIPITATION FELL AND THE AMOUNTS OF PRECIPITATION IN THE LAFAYETTE AREA BY MONTH AND YEAR

	1961		1962		1963		Average	
Month	No. of Days Precip. Fell	Inches of Precip.	No. of Days Precip. Fell	Inches of Precip.	No. of Days Precip. Fell	Inches of Precip.	No. of Days Precip. Fell	Inches of Precip.
Jan.	10	0.49	16	4.11	14	0.50	13	1.70
Feb.	10	1.60	14	1.78	15	0.78	13	1.39
Mar.	14	6.11	14	2.85	21	4.35	16	4.44
Apr.	17	5.21	11	1.48	10	4.11	13	3.60
May	12	3.50	14	5.15	10	2.03	12	3.56
June	10	3.71	7	2.77	6	1.74	8	2.74
July	14	2.63	14	6.84	13	4.85	14	4.77
Aug.	9	1.88	7	3.41	7	3.16	8	2.82
Sept.	9	2.80	10	1.97	5	1.03	8	1.93
Oct.	14	4.13	10	3.75	6	0.63	10	2.84
Nov.	13	2.53	8	0.86	9	2.63	10	2.01
Dec.	19	1.13	11	0.38	9	0.69	13	0.73
Total	151	35.72	136	35.35	125	26.50	138	32.53

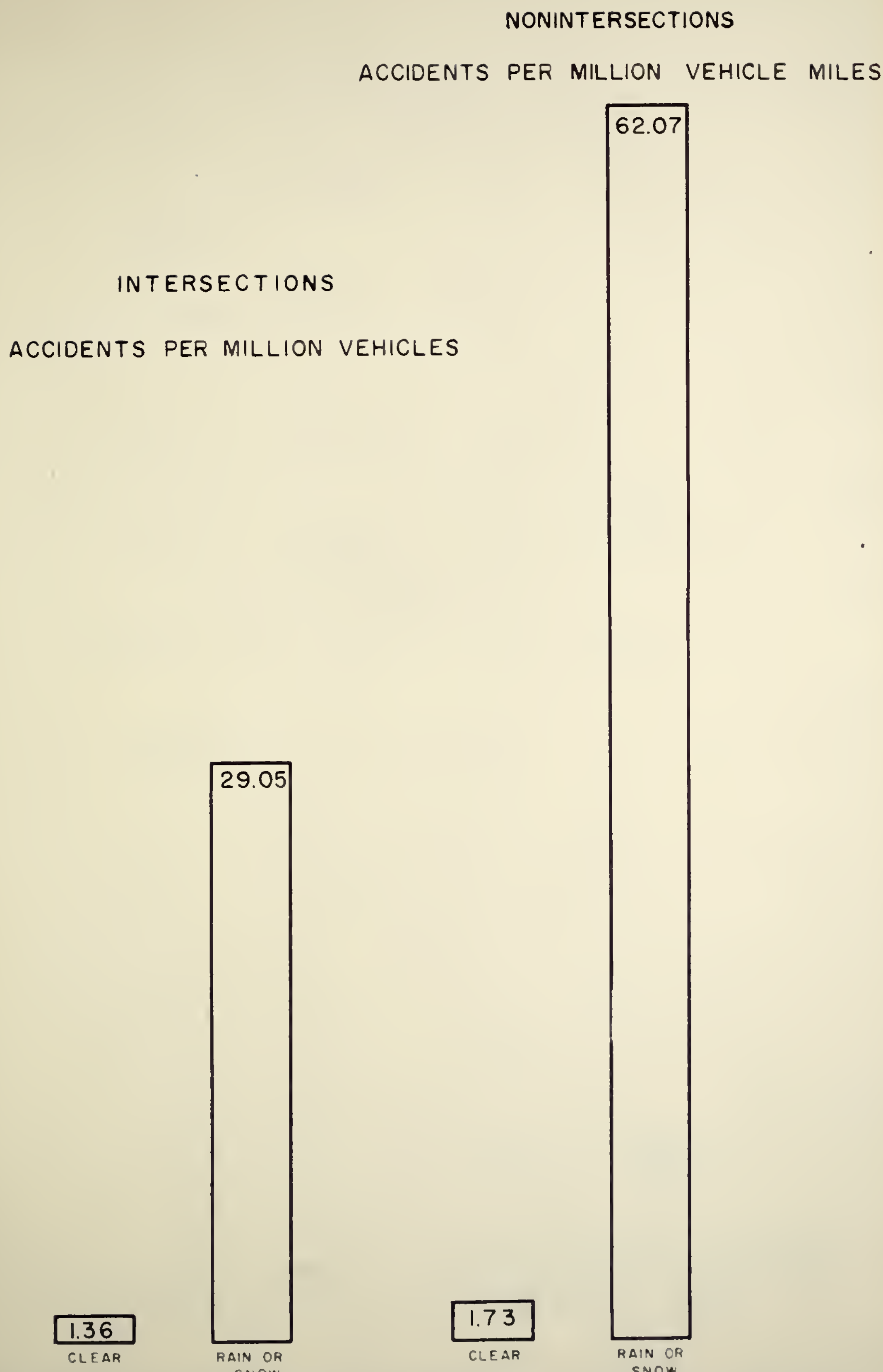


FIGURE 36 AVERAGE ANNUAL ACCIDENT RATE FOR CLEAR AND INCLEMENT WEATHER FOR 1961, 1962 AND 1963.

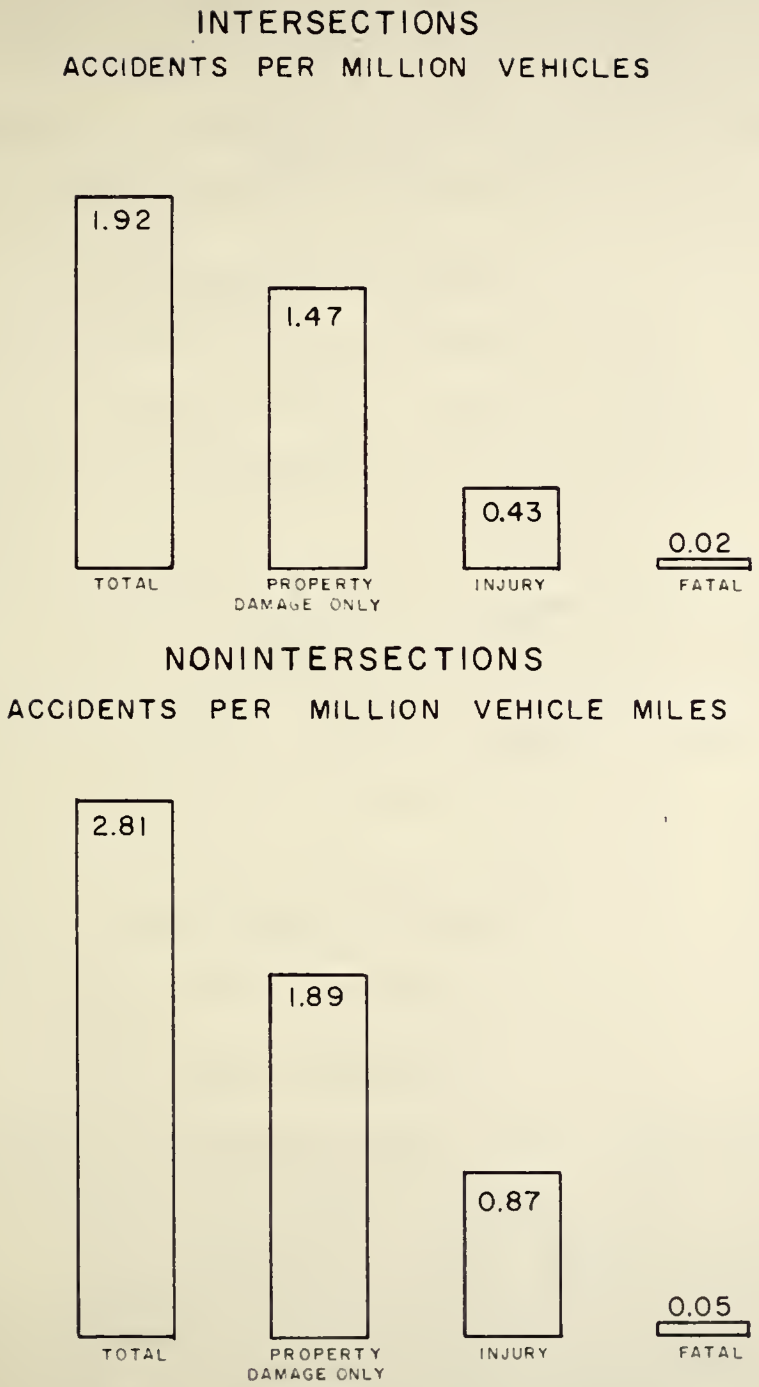


FIGURE 37 AVERAGE ANNUAL ACCIDENT RATES BY DEGREE OF SEVERITY FOR 1961, 1962 AND 1963.

compared in Figure 38. Approximately one-third of the vehicle miles are travelled on weekends but 42 percent of the accidents occurred during this period. While driving about 38 percent of the vehicle miles, night-time drivers had only 29 percent of the accidents.

Accident Distribution

The distribution of accidents is shown in Table 24. Those days having three or more accidents were examined in detail. The days having three or more accidents are shown in Tables 25, 26 and 27 for 1961, 1962 and 1963 respectively.

Sixty-one percent of the accidents on these days occurred while it was raining or snowing. Accidents occurring on Friday, Saturday or Sunday also represented 61 percent of the total of these accidents.

Approximately 18 percent of these accidents happened on a holiday or other high volume day.

In general inclement weather and weekend or holiday traffic added significantly to the number of accidents.

Costs of Accidents

Accidents were classified according to the following definitions (8):

Type I — Intersection accidents which occur at the crossing of two traffic streams. These accidents are typically right-angle, turning and rear-end collisions.

Type II — Marginal accidents which occur along the moving edge of a traffic stream. These accidents result from vehicles attempting to enter or leave the moving stream. Typical accidents are rear-end collisions.

Type III — Medial accidents which occur between vehicles moving in opposite directions. Head-on collisions and side-swipes are typical accidents of this type.

TABLE 24

DAILY ACCIDENT FREQUENCY

Number of Accidents/Day	Number of Days with Given Number of Accidents/Day	Percentage of Total Days having Given No. of Acc./Day	Number of Accidents
0	575	52.5	0
1	322	29.5	322
2	135	12.3	270
3	33	3.0	99
4	16	1.5	64
5	6	0.5	30
6	2	0.2	12
7	3	0.3	21
8	2	0.2	16
	1095	100.0	834

100% of the accidents happened on 47.5% of the days
61% of the accidents happened on 18.0% of the days
29% of the accidents happened on 5.7% of the days
17% of the accidents happened on 2.8% of the days

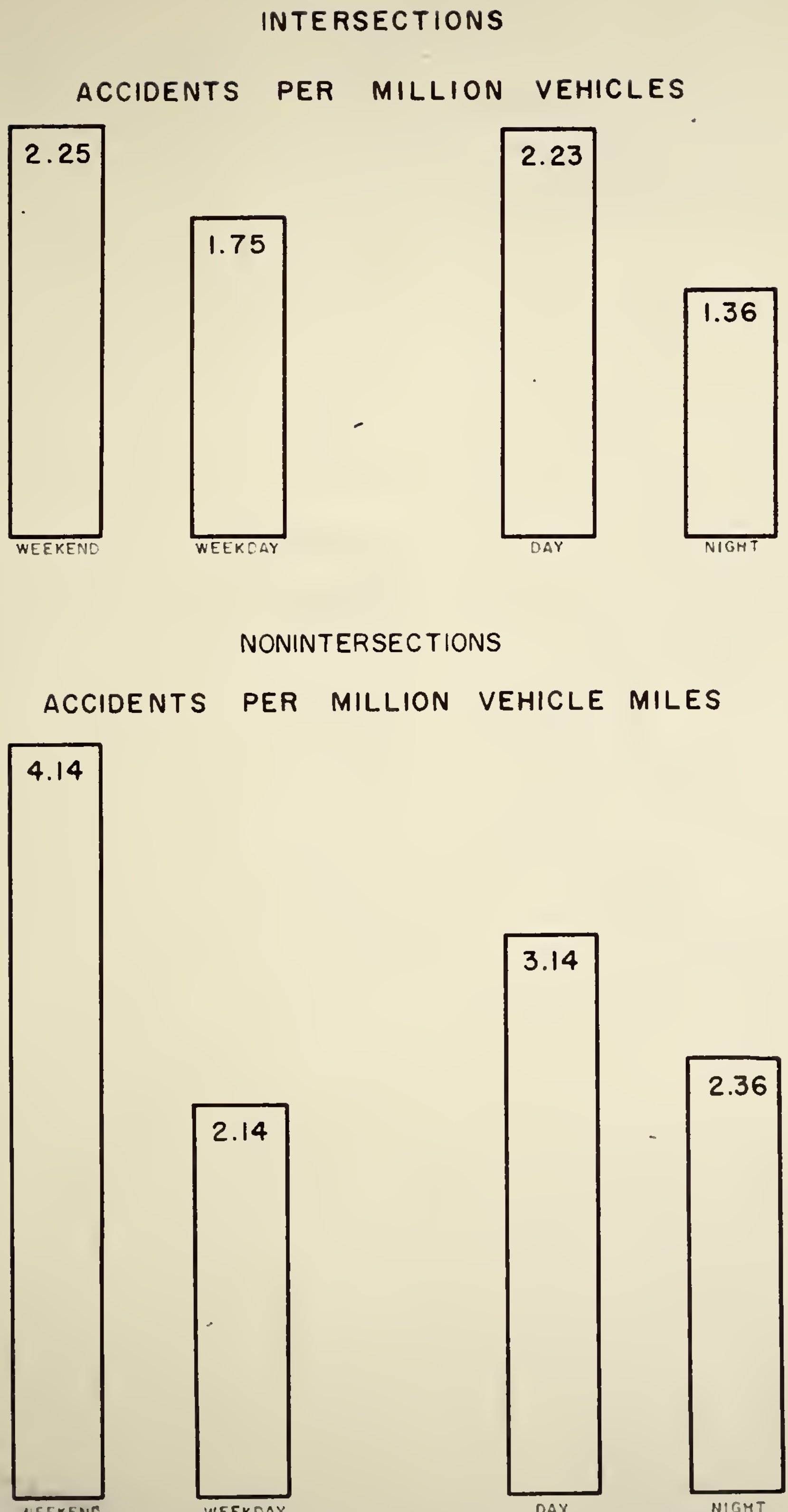


FIGURE 38 AVERAGE ANNUAL ACCIDENT RATES BY WEEKEND, WEEKDAY, DAY AND NIGHT FOR 1961, 1962 AND 1963.

TABLE 25

DAYS OF YEAR HAVING THREE OR MORE ACCIDENTS, 1961

Date	No. of Acc.	Day of Week	Weather			Remarks
			C	R	S*	
Feb. 3	4	Friday	2	0	2	
Mar. 12	3	Sunday	1	2	0	
18	5	Saturday	0	5	0	
31	4	Friday	1	3	0	Good Friday
May 9	3	Tuesday	0	3	0	
June 22	3	Thursday	1	2	0	
July 19	3	Wednesday	0	3	0	
28	7	Friday	4	3	0	
Aug. 10	3	Thursday	0	3	0	
Oct. 19	4	Thursday	0	4	0	
28	4	Saturday	2	2	0	Football Game
Nov. 19	3	Sunday	0	1	2	
22	4	Wednesday	0	4	0	Day before Thanksgiving
13	50		11	35	4	

* C - Clear, R - Rain, S - Snow

TABLE 26

DAYS OF YEAR HAVING THREE OR MORE ACCIDENTS, 1962

Date	No. of Acc.	Day of Week	Weather C	R	S*	Remarks
Jan. 5	3	Friday	0	3	0	
7	3	Sunday	1	0	2	
15	5	Monday	2	0	3	
Feb. 23	3	Friday	0	0	3	
Mar. 18	3	Sunday	3	0	0	
21	3	Wednesday	1	2	0	
Apr. 22	3	Sunday	0	3	0	Easter
May 2	3	Wednesday	1	2	0	
18	3	Friday	3	0	0	
July 13	5	Friday	1	4	0	
15	3	Sunday	3	0	0	
24	3	Tuesday	2	1	0	
Aug. 25	7	Saturday	0	7	0	
Sept. 5	3	Wednesday	3	0	0	
Oct. 16	3	Tuesday	3	0	0	
20	8	Saturday	0	8	0	Football Game
Nov. 21	3	Wednesday	3	0	0	Day before Thanksgiving
Dec. 15	3	Saturday	3	0	0	
22	4	Saturday	0	1	3	Weekend before Christmas
19	71		29	31	11	

* C-Clear, R-Rain, S-Snow

TABLE 27

DAYS OF YEAR HAVING THREE OR MORE ACCIDENTS, 1963

Date	No. of Acc.	Day of Week	Weather C	R	S*	Remarks
Feb. 9	3	Saturday	1	0	2	
23	6	Saturday	3	0	3	
24	4	Sunday	3	0	1	
Mar. 31	5	Sunday	0	5	0	
Apr. 13	3	Saturday	2	1	0	Day before Easter
19	4	Friday	2	2	0	
28	3	Sunday	3	0	0	
May 17	4	Friday	0	4	0	
19	7	Sunday	0	7	0	
27	4	Monday	0	4	0	
28	4	Tuesday	0	4	0	
July 6	3	Saturday	0	3	0	Fourth of July Weekend
13	6	Saturday	0	6	0	
14	3	Sunday	3	0	0	
17	3	Wednesday	2	1	0	
20	4	Saturday	4	0	0	
Aug. 19	5	Monday	0	5	0	
21	4	Wednesday	4	0	0	
Sept. 7	3	Saturday	1	2	0	
Oct. 24	3	Thursday	3	0	0	
29	3	Tuesday	3	0	0	
31	3	Thursday	0	3	0	
Nov. 4	3	Monday	1	2	0	
13	3	Wednesday	0	2	1	
22	4	Friday	0	4	0	Day after Thanksgiving
Dec. 1	3	Sunday	3	0	0	
8	4	Sunday	0	0	4	
20	4	Friday	4	0	0	
21	8	Saturday	8	0	0	
24	4	Tuesday	4	0	0	Day before Christmas
30	120		54	55	11	

* C - Clear, R - Rain, S - Snow

Type IV Internal stream accidents which occur among vehicles moving in the same direction. These include such miscellaneous accidents as running off the road, overturning and some rear-end collisions. This type of accident will occur on any facility.

The amount of property damage for each accident was available from the State Police accident report except that values for vehicles that were a "total loss" were not noted. Therefore an estimated value based on prices in a used car retail price book was used. Injury costs were conservatively estimated at $660 per injury (2). Deaths were assigned an average value of $33,000 per fatality (4). A summary of these costs by type of accident and year for property damage, injury and death losses is given in Table 28.

TABLE 28

TOTAL COST OF ACCIDENTS ON U. S. 52 BY-PASS
1961 - 1962 - 1963

Type of Accidents	1961	1962	1963	Total
		Property Damage		
I	64,560	64,250	91,140	219,950
II	32,680	28,540	29,820	91,040
III	12,240	10,210	18,280	40,730
IV	12,140	12,760	13,090	37,990
Total	121,620	115,760	152,330	389,710
		Injury		
	1961	1962	1963	Total
I	30,580	41,530	67,950	140,060
II	13,790	18,730	30,650	63,170
III	4,760	6,460	10,570	21,790
IV	4,330	5,880	9,630	19,840
Total	53,460	72,600	118,800	244,860
		Fatal		
	1961	1962	1963	Total
I	66,000	66,000	--	132,000
II	--	--	33,000	33,000
III	99,000	33,000	33,000	165,000
IV	--	--	--	---
Total	165,000	99,000	66,000	330,000
			GRAND TOTAL	964,570

SUMMARY OF RESULTS AND FINDINGS

The results and findings of this research study of the U. S. 52 By-Pass at Lafayette, Indiana, are summarized in the following paragraphs:

General

1. The number of accidents on U. S. 52 in Fairfield and Wabash Townships increased approximately 50 percent from 1956 to 1964.
2. Approximately 57 percent of the by-pass accidents occurred within 100 feet of an intersection while about 65 percent happened within 200 feet of an intersection.

Multiple Linear Regression

1. This statistical technique provided a means of determining the independent variables that were significant in predicting various accident rates.
2. Twenty-nine regression equations for various intersection accident rates and 27 equations for nonintersection accident rates were computed. The model for accidents per 100 million vehicles accounted for 76 percent of the variability in this intersection accident rate on the by-pass. The model for accidents per 100 million vehicle miles accounted for 33 percent of the variability in this nonintersection accident rate on the by-pass.

3. For intersections, accidents per 100 million vehicles increased when:

   a. Percent green time on the by-pass decreased

   b. By-pass, cross street or total ADT increased

   c. Percent right or left turns from the by-pass increased

   d. Maximum approach speed increased

   e. Number of intersection approaches increased

   f. Total width of driveways within 200 feet of the intersection increased

4. For nonintersection study sections, accidents per 100 million vehicle miles increased when:

   a. Total number of establishments per mile increased

   b. Total number of driveways per mile increased

   c. Total number of low volume intersections per mile increased

   d. Geometric modulus increased

   e. ADT increased

   f. Operating speed decreased

   g. Total width of driveways per mile increased

   h. Length of intersection turning lanes in the section increased

Quality Control

1. Quality control analysis is an excellent technique for determining those sections or intersections of a highway that are "out of control" or that probably have an assignable cause for the high or low accident rate.

2. Intersection number 14 (Teal Road) was out of control the two years prior to the installation of a traffic signal and also during the first year in which the signal was in use.

3. Those intersections consistently above the average accident rate were numbers 13 (S. R. 38) and 14 (Teal Road) while those consistently below average were 2 (Yeager), 7 (Underwood), 11 (Kossuth) and 12 (McCarty).

4. Nonintersection study section number 4 was out of control in both 1961 and 1962 but in 1963 had no accidents. Sections 18 and 19 were out of control in 1963.

5. In the three year study period those sections consistently below the average were sections numbered 2, 5, 6, 8, 10, 16, 20 and 24. Those consistently above average were sections numbered 14, 17, 18, 19 and 21.

Accident Rates

1. Intersection accident rates were computed and evaluated by 11 methods. The intersections most often ranked by exposure, cost and severity measures as the most hazardous were 14 (Teal Road), 10 (S. R. 26), 6 (S. R. 25) and 8 (Greenbush) in decreasing order of hazard. All methods listed Teal Road as the most dangerous intersection on the by-pass.

2. Those intersections most frequently ranked by exposure, cost and severity measures as the safest intersections were 2 (Yeager), 11 (Kossuth), 7 (Underwood), 12 (McCarty) and 5 (Ninth Street Cutoff) in increasing order of hazard. Nine of the 11 methods listed 2 (Yeager) as the safest intersection on the by-pass.

3. The number of accidents per MV includes a consideration of exposure and is highly correlated with the severity and cost of accidents on the by-pass. This accident rate provided a satisfactory measure of

the hazard at an intersection and was used in comparing intersections in other parts of this study.

4. The nonintersection study sections most often ranked by exposure, cost and severity measures as the most hazardous were 14, 17, 18, 19 and 21. Those considered the safest were 2, 3, and 24.

5. Accidents per million vehicle miles, the most commonly used accident rate for sections of highway, was used to compare nonintersection study sections on the by-pass. This rate was correlated with accident cost and injury accidents per millions vehicle miles.

Collision Diagrams

1. There is no substitute for the use of collision-condition diagrams for the determination of specific causes of high accident rates at intersections as well as nonintersection study sections.

2. The installation of traffic signals on the by-pass during the study period (Salisbury, S. R. 38 and Teal Road) resulted in an increase in rear-end collisions, lane-changing accidents, injury accidents and total accidents. While vehicles on the by-pass were involved at a much higher rate after the signal installations, cross street traffic involvement rates remained the same or decreased. Right-angle and left-turn accidents decreased.

3. Following the construction of extra approach and recovery lanes (a "passing blister") at Ninth Street Cutoff in 1962 a reduction of 50 to 80 percent of all types of accidents was realized.

4. A substantial number of accidents at intersections occurred when vehicles changed lanes or passed left-turning vehicles on the right.

5. Several accidents occurred when two vehicles passing through the intersection side-by-side were forced into the same lane when the exit lane terminated.
6. The left-turn movement of northwest bound by-pass traffic at Northwestern Avenue is a dangerous one. Another hazardous movement is the left turn on to the by-pass by southeast bound traffic.
7. During the three year study, 23 of the 31 accidents at Happy Hollow Road involved west bound vehicles nearing the crest of a steep hill. In addition to the limited sight distance, the fastest moving west bound vehicles were also in the same lane as left-turning vehicles because of a slow traffic lane on the right.
8. Nearly one-third (18) of the accidents at S. R. 25 (the third most hazardous intersection) resulted from improper lane usage. Ten of these accidents happened in approach lanes and eight in exit lanes.
9. All of the 14 accidents at Underwood Street during the three year period involved left-turning vehicles. Thirteen of these accidents involved north bound vehicles.
10. At Greenbush Street all types of accidents increased in 1963 over 1962 or 1961.
11. The Union Street intersection accident rate for 1962 was about one-half that of 1961 or 1963.
12. South bound vehicles had a higher involvement rate than the other directional involvement rates at S. R. 26, the second most hazardous and the busiest intersection on the by-pass. On the by-pass as a whole, north bound vehicles had the highest involvement rate.
13. Ten of the 15 accidents at Kossuth Street involved left-turning vehicles. Seven of these ten involved north bound traffic.

14. At McCarty Lane four accidents were right-angle collisions while six others involved south bound vehicles changing lanes.
15. Rear-end accidents occurred four times as often after the traffic signal installation at S. R. 38 as before. The number of by-pass vehicles in accidents more than doubled after the change while the number of vehicles in accidents on the cross streets decreased by 25 percent.
16. All methods used in this study indicated that Teal Road was the most hazardous intersection on the by-pass. Following the installation of the traffic signal in January 1963, rear-end and lane-change accidents increased by a factor of eight. The only type of accident to decrease was left-turn accidents. Left-turn lanes were constructed on the by-pass when the signal was installed.
17. On the Wabash River Bridge six of the nine accidents occurred when the pavement was wet or icy.
18. Seven of the 11 accidents on section 10 happened at night. Six of the total accidents were on wet or icy pavement.
19. One-half of the nonintersection accidents occurred on sections 17 through 21. On this 1.6 miles of highway, 58 percent of the accidents involved marginal friction, two-thirds of the accidents occurred during the peak accident rate hours and 35 percent of the accidents occurred when the pavement was wet or icy.

Other Analyses

1. Over 62 percent of the daily accidents occurred during the hours from 1-2 A.M., 7-8 A.M. and 1-8 P.M. During these nine hourly periods 59 percent of the injuries and 50 percent of the fatalities occurred.

2. Friday and Saturday accident rates were one and one-half that of the weekday rates while Sunday accident rates were nearly twice that for the weekday.
3. High volumes of through traffic and inclement weather were factors which probably contributed to the high accident rates of certain months.
4. Involvement rates were higher for passenger cars, Tippecanoe County vehicles and northwest bound vehicles when compared with trucks, non-Tippecanoe County vehicles and southeast bound vehicles respectively.
5. Inclement weather (rain or snow) accident rates were approximately 21 and 36 times greater than clear weather accident rates for intersections and nonintersection study sections respectively.
6. The ratio of fatal accidents to injury, to property damage, and to total accidents was approximately 1:21:61:83 for the U. S. 52 By-Pass as compared with 1:33:97:131 for Indiana in 1963.
7. Weekend accident rates were greater than weekday accident rates and day accident rates were higher than night accident rates. These comparisons were true for intersections as well as nonintersection study sections.
8. Sixty-one percent of the accidents that occurred on the days that had three or more accidents happened while it was raining or snowing. Friday, Saturday or Sunday also had 61 percent of these accidents.
9. The total cost of accidents on the U. S. 52 By-Pass during the three year study period was nearly a million dollars.

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APPENDIX A

TRAFFIC ACCIDENT PUNCH CARD CODES

INDIANA STATE POLICE

APPENDIX A

TRAFFIC ACCIDENT PUNCH CARD CODES

INDIANA STATE POLICE

The following codes are for use with eighty column punch cards. The effective date for use of these codes was January 1, 1961.

Card Column	Description and Instructions
1	Card Number

This column indicates the number of punch cards needed to contain the information from a particular accident report.
The first card for any particular accident report will be referred to as the lead card and all additional cards for that accident report will be referred to as supplementary cards.
Zero "0" code means that the accident involved only 1 vehicle and that there was not more than one person injured or killed.
A one "1" code means that there were two or more vehicles, or two or more people injured or killed. A one "1" code for a particular accident must have at least one additional card. The second card will contain a two "2" code, the third card a three "3" code, and etc. It will be noted that using this coding method there will be only nine "9" possible codes, therefore the ninth card and all additional cards over nine will be coded nine "9".
This column must be coded on all cards.

2 thru 7	Accident Number

The accident number is printed on the accident report by the accident records section.
This number, which is used to identify a particular accident, is placed in the six columns two through seven.
The units position must be in column seven and each column must be filled. The number 563 would be entered as 000563.

2 thru 7 Accident Number

All of these columns must be coded on the lead card only. They will be reproduced on the supplementary cards.

8 Type of Accident

An accident type is determined by the first event happening on the road as prescribed in the "Uniform Definitions of Motor Vehicle Accidents".

R Collision with pedestrian.
X Collision with other motor vehicle.
0 Collision with railroad train.
1 Collision with farm vehicle.
2 Collision with animal drawn vehicle.
3 Collision with bicycle.
4 Collision with animal.
5 Collision with fixed object.
6 Collision with all other objects.
7 Overturned in roadway.
8 Ran off roadway.
9 All other non-collision.

This column must be coded on lead card only. It will be reproduced on the supplementary cards.

9 Investigation or Source

This code shows if the accident was investigated and if so by what department.
A zero "0" code means the accident was not investigated and all information is obtained from an operators report.

Code one "1" indicates a state police investigated accident.
Code two "2" is sheriff investigated accident.
Code three "3" is city police investigated accident.
Code four "4" is other investigated accident.

This column must be coded on lead card only. It will be reproduced on the supplementary cards.

10 and 11 Directional Analysis

These codes are used to modify the type of accident code in column 8 for certain types only.
If column 8 is coded "R" for collision with pedestrian then one of the 6 codes under "Pedestrian" must be used.

10
and
11 Direction Analysis

If column 8 is coded "X" for collision with other motor vehicle then one of the 9 codes under "Motor Vehicle Collision-Intersection", or one of the 10 codes under "Motor Vehicle Collision-Non Intersection" must be used.
If column 8 is coded "0" use code 40 only.
If column 8 is coded "1" or "6" use code 45 only.
If column 8 is coded "2" use code 41 only.
If column 8 is coded "3" use code 42 only.
If column 8 is coded "4" use code 43 only.
If column 8 is coded "5" use code 44 only.
If column 8 is coded "7" use code 50 only.
If column 8 is coded "8" use code 60 only.
If column 8 is coded "9" use code 70 or 80, which ever one applies to the situation.
These columns must coded on the lead card only. They will be reproduced on the supplementary cards.

Pedestrian

10 Car going straight.
11 Car turning right.
12 Car turning left.
13 Car backing.
18 All others.
19 Not stated.

Motor Vehicle Collision-Intersection.

20 Entering at angle.
21 From same direction-both going straight.
22 From same direction-one turning, one straight.
23 From same direction-one car stopped.
24 From same direction-all others.
25 From opposite directions-both going straight.
26 From opposite directions-one left, other straight.
28 All others.
29 Not stated.

Motor Vehicle Collision - Non Intersection

30 Going in opposite directions, both moving.
31 Going in same direction, both moving.
32 One car parked.
33 One car stopped in traffic.
34 One car entering parked position.
35 One car leaving parked position.
36 One car entering alley or driveway.

10
and
11 Directional Analysis

37 One car leaving alley or driveway.
38 All others.
39 Not stated.

All Other Accidents.

40 Collision with train.
41 Collision with animal drawn vehicle.
42 Collision with bicycle.
43 Collision with animal.
44 Collision with fixed object.
45 Collision with other object.
50 Overturned in roadway.
60 Left roadway
70 Fell from moving vehicle.
80 All others.

12
thru
15 Property Damage Loss

The dollar amount of property damage is used to determine the amount of money lost each year due to traffic accident damage. To arrive at the direct reading code, add together all estimates of amount of damage to all vehicles, round off the total to the nearest 10 dollars, drop the cent amount and the unit dollar position and enter the remaining figure. If amount is not stated code 0000.

All columns must be filled on lead card only. They will be reproduced on the supplementary cards.

Less than 15.00	Code 0001
15.00 to 24.00	Code 0002
25.00 to 35.00	Code 0003
130.00 to 134.00	Code 0013
9,990.00 to 9,994.00	Code 0999

Any accident with more than 100,000.00 damage code 9999 and enter actual amount on the card in red pencil.

16 Character of Location

The character of location is used to show if the accident occurred at an intersection, and if not, what was significant about the location. If none of the coded features were present, use code 8.

16 Character of Location

If columns 10 and 11 are coded in the 20 series "Motor Vehicle Collision-Intersection" this column must be coded "1".
If columns 10 and 11 are coded in the 30 series "Motor Vehicle Collision-Non Intersection" this column must be coded some code 2 through 8.
This column must be coded on lead card only. It will be reproduced on the supplementary cards.

1 Intersection. Street and/or highway intersection.
2 Culvert.
3 Intersection. Alley or driveway. This includes any intersection other than regular street and/or highway intersection.
4 Railroad crossing.
5 Bridge or overpass.
6 Underpass.
8 All others.
9 Not stated.

17 and 18 Month of Accident

Enter in these columns the numerical value of the month in which the accident occurred. Two digits must be used. Numberical values of January thru September must be preceeded by a zero. The only possible codes are 01 thru 12.
These columns must be coded on lead card only. They will be reproduced on the supplementary cards.

19 and 20 Date

These columns are used to show the date of the month on which the accident occurred. Dates prior to the tenth of the month must be preceeded by a zero. The only possible codes are 01 thru 31.
These columns must be coded on lead cards only. They will be reproduced on the supplementary cards.

21 Year

This column indicates the year in which the accident occurred. By using one full column it is possible to code ten years without repeating a code. The code is determined by using the unit position of the year.
This column must be coded on lead card only. It will be reproduced on the supplementary cards.

22 Day of Week

This column indicates on which of the 7 days of the week the accident occurred. The only possible codes are 1 thru 7.
This column must be coded on lead cards only. It will be reproduced on the supplementary cards.

1 Monday
2 Tuesday
3 Wednesday
4 Thursday
5 Friday
6 Saturday
7 Sunday

23 and 24 Hour of Day

The hour code is based upon the 24 hour clock system plus 1. All minutes are dropped and the stated hour only is used. The only possible codes are 01 thru 24 with "Not Stated" being coded 99.
Both columns must be filled on lead card only. They will be reproduced on supplementary cards.
In converting to hourly code, add one to any stated time from 1.00 AM to 12.59 PM. Add 13 to any time from 1.00 PM to 11.59 PM.

01 Midnight to 12.59 AM
02 1.00 AM to 1.59 AM
03 2.00 AM to 2.59 AM
04 3.00 AM to 3.59 AM
05 4.00 AM to 4.59 AM
06 5.00 AM to 5.59 AM
07 6.00 AM to 6.59 AM
08 7.00 AM to 7.59 AM
09 8.00 AM to 8.59 AM
10 9.00 AM to 9.59 AM
11 10.00 AM to 10.59 AM
12 11.00 AM to 11.59 AM
13 Noon to 12.50 PM
14 1.00 PM to 1.59 PM
15 2.00 PM to 2.59 PM
16 3.00 PM to 3.59 PM
17 4.00 PM to 4.59 PM
18 5.00 PM to 5.59 PM
19 6.00 PM to 6.59 PM
20 7.00 PM to 7.59 PM
21 8.00 PM to 8.59 PM
22 9.00 PM to 9.59 PM
23 10.00 PM to 10.59 PM
24 11.00 PM to 11.59 PM
99 Not stated.

25
and
26 County

Accidents in rural areas, those outside of incorporated cities and towns, are chargeable to the county in which they occurred with the exception of toll roads. Toll road accidents are chargeable to the toll road either in it's entirety or by milepost and not to the county.

The county is coded on toll road accidents for special study purposes. The county is coded in urban accidents. The only possible county codes are 01 thru 92 as listed in the county codes.

These columns must be coded on lead cards only. They will be reproduced on the supplementary cards.

27 Population Group

All accidents outside of corporate limits will be coded "0".

All accidents within corporate limits will be coded according to the population grouping of the city or town.

This column must be coded on all lead cards. It will be reproduced on all supplementary cards.

0 Rural accident.
1 City or town under 1,000.
2 1,000 to 2,500.
3 2,500 to 5,000.
4 5,000 to 10,000.
5 10,000 to 25,000.
6 25,000 to 50,000.
7 50,000 to 100,000.
8 100,000 to 250,000.
9 250,000 and over.

28
thru
31 City or Township

Urban accidents - incorporated cities and towns.

All cities carry a code number higher than 1000 therefore all four columns will be used. All city codes end in an even number. They are also divisible by four.

Rural accidents.

Codes for townships will always be numbers under 30, therefore place zeros in columns 28 and 29 and the township number in columns 30 and 31.

This will make a four digit number. In case of toll road use four zeros in these columns.

These columns must be coded on all accidents.

32 thru 34 Highway Number

Use low number if two state roads or two federal roads run concurrently. If a state and federal road run concurrently, use the federal road number. Use interstate road number in preference to any of the above.
Leave columns blank for county roads or city streets, even if the county roads or city streets are numbered. Leave blank for the toll road. Use preceding zeros to fill the field, when coded. Code lead cards only as required.

35 Additional Highway Information

This column serves two purposes. It modifies the highway number and it identifies a directional lane on a toll road. The column must be coded for all toll road accidents. On all other accidents code only when additional information is needed to identify the road on which the accident occurred.
Code lead cards only as required.

1 Alternate, as 31A.
2 East, for 31E etc.
3 West.
4 North.
5 South.
6 Eastbound lane for toll road.
7 Westbound lane for toll road.
8 Northbound lane.
9 Southbound lane.

36 Highway Classification

The classification of the road coded in columns 32 thru 34 is shown in this column. If the accident occurred on a county road, city street or toll road, columns 32 thru 34 will not be coded, however, this column must indicate why by using a "0" code for county road or city street, or using a "4" code for a toll road.
This column must be coded on all lead cards. It will be reproduced on supplementary cards.

0 County road or city street.
1 State road.
2 Federal road excluding interstate.
3 Interstate.
4 Indiana toll road

37
thru
40 Intersecting Highway Number

At the present time column 37 is always left blank. A four position field was set aside to be used for a highway log number sometime in the future.
If the accident occurred at an intersection, indicate the intersecting road number in the columns 38 thru 40.
Code the intersecting road number in the same manner the highway number was coded in columns 32 thru 34. If the accident occurred on the toll road, place the milepost number in these columns. Use preceding zeros to fill the field, when coded.
Code this field on lead cards only when indicated by above instructions.

41 Vehicle Number

Code in this column the number assigned to this vehicle in this accident. For example, if there were 5 vehicles in the accident we will need five cards, one for each vehicle. The first card will contain the number "1", the second card the number "2" and so on to the fifth card. It will be noted that by using one column we can number only nine vehicles. If the accident involves more than nine vehicles code the first nine in the above manner and code all succeeding vehicles as 9. It is therefore possible, in a 12 car accident to have 12 cards with the first nine cards coded 1 thru 9 and 3 additional cards coded 9.

42
and
43 Type of Vehicle

After the vehicle is numbered in column 41, code in these columns the type of vehicle.

01 Passenger car
02 Passenger car with trailer
03 Passenger car with house trailer
04 Truck
05 Truck with trailer
06 Truck tractor
07 Truck tractor and semi-trailer
08 Other combination
09 Farm tractor or other self propelled farm equipment
10 Taxi cab
11 Bus
12 School bus
13 Motorcycle
14 Motor bike

42
and
43

Type of Vehicle

15 Motor scooter
16 Not used
17 Not used
18 Other type vehicles
19 Not stated

44

Special Vehicle Information

This column is coded only if the vehicle in column 42 and 43 is in one of the following catagories.

1 Emergency vehicle on emergency run. Police, fire, etc.
2 Military vehicle.
3 Any other public owned vehicle.

45
and
46

Age of Driver

Code the age of the driver of the vehicle which is numbered in column 41 with the following exceptions.

If the vehicle was parked, indicating there was no driver, leave these columns blank.
If the driver of the vehicle was guilty of hit and run, indicating the age was not known at the time of the accident, leave these columns blank.
If the vehicle was a driverless moving vehicle, leave these columns blank.
If the age of the driver was not stated or otherwise not known, code and "X" in column 45 and leave column 46 blank.

47

Sex of Driver

This column serves two purposes. It will show the sex of the driver if it is stated and will indicate if the sex is not stated and in four cases will indicate why the sex is not stated.

1 Male
2 Female
3 Hit and run. Sex assumed unknown
4 Driverless moving vehicle
5 Properly parked
6 Improperly parked
9 Not stated

48 Proximity of Residence

0 Non resident of state
1 Residing in same county as accident occurred
2 Residing elsewhere in state
9 Not stated

49 Drivers License

The driving experience of the driver and the type of licence, within certain limits, if any, may be determined by this column.

1 Licensed in state. Operators, chauffers, etc.
2 Licensed in state. Beginners, school permit, etc.
3 Resident of state, no license.
4 Non resident, licensed in other state.
5 Non resident, no license.
9 Not stated.

50 Deaths

Indicate here the number of people killed as a result of this accident. If more than 9 were killed code as 9 only. If there were no deaths use code "0".
This column must be coded on all lead cards. It will be reproduced on supplementary cards.

51 Injured

Indicate here the number of people injured, not fatally, as a result of this accident. If more than 9 were injured code as nine only.
If there were no non fatal injuries use code "0".
This column must be coded on all lead cards. It will be reproduced on supplementary cards.

52 Severity of Accidents.

If column 50 contains any number 1 thru 9, indicating a fatality, use code 1 in this column.
If column 50 contains code 0 check column 51. If column 51 contains any number 1 thru 9, indicating an injury and column 50 contains code 0, use code 2 in this column.
If both columns 50 and 51 contain code 0, indicating no deaths and no injuries, use code 3 in this column.
This column must be coded on all lead cards. It will be reproduced on the supplementary cards.

1 Fatal
2 Non fatal injury
3 Property damage only

53 and 54 Age of Injured or Killed

The age of the injured or killed person will be entered in these columns. If the age is unknown use code "X" in column 53 and leave column 54 blank.

55 Sex of Injured or Killed

This column indicates the sex of the injured or killed person.

Person

1 Male
2 Female
9 Not stated

56 Location of Injured or Killed

Show in this column where the person was at the time of the accident. Driver, passenger, etc.

1 Driver
2 Passenger
3 Pedestrian
4 Bicyclist
8 All others
9 Not stated

57 Car Occupied by Injured or Killed

If column 56 is coded 1 or 2 indicate in this column which of the vehicles coded in column 41 was occupied by this person.

58 Severity of Injury

Code the severity of the injury in this column using the code number for the most serious injury to this person indicated on the report.

1 Died as result of accident.
2 Visible signs of injury, as bleeding wound, distorted limbs or had to be carried away. "A".
3 Other visible injuries, as bruises, swelling, abrasions, limping, etc. "B".
4 No visible injuries, but complaint of pain or momentary unconsciousness. "C".

Columns 59 to 71 are to be coded from investigators reports only.

59 Test for Alcohol

0 No chemical test offered.
1 Test offered but refused.
2 Breath test given.
3 Blood test given.
4 Urine test given.
9 Not stated.

60 Arrests

This column indicates if the driver was or was not arrested. If the driver was arrested show if it was for "Driving Under the Influence of Intoxicants" or for some other violation.

0 Driver not arrested
1 Arrested for driving under the influence of intoxicants
2 Arrested for other violation
9 Not stated

61 Speed Limit

Code the speed limit existing at the location of the accident as stated by the investigating officer.

R 20 MPH
X 25 MPH
0 30 MPH
1 35 MPH
2 40 MPH
3 45 MPH
4 50 MPH
5 55 MPH
6 60 MPH
7 65 MPH
8 Other
9 Not stated

62 Speed Before Accident

This column refers to the speed of the vehicle coded in column 41 of the same card. Use the speed indicated by the investigating officer.

X Stopped or standing still excluding vehicle properly parked.
0 Under 10 MPH
1 10 to 19 MPH
2 20 to 29 MPH

62 Speed Before Accident

3 30 to 39 MPH
4 40 to 49 MPH
5 50 to 59 MPH
6 60 to 69 MPH
7 70 to 79 MPH
8 80 MPH or over
9 Not stated

63 Contributing Circumstances

Code in this column the one violation or circumstance which seems to have been the major cause of, or contributed most to the cause of the accident.

1 Speed too fast
2 Failed to yield right of way
3 Drove left of center not in passing
4 Improper overtaking
5 Failed to stop for stop sign
6 Disregarded traffic signal
7 Followed too closely
8 Made improper turn
9 Other improper driving
0 Inadequate brakes
X Improper lights
R Had been drinking

64 Vehicle Defects

This column indicates vehicle defects which could have also contributed to the accident.

0 No defects
1 Brakes defective
2 Lights defective
3 Defective steering
4 Puncture or blowout
8 Other defects
9 Not stated

65 Vision Obscurement

This column will indicate driver vision obscurement

0 Not obscrued
1 By buildings
2 By embankment
3 By signboard
4 By trees, crops, etc.
5 By hillcrest
8 All others
9 Not stated

66 Drivers Actions, Miscellaneous

Code the action the driver was performing, voluntary or otherwise, just prior to the accident.

0 Passing
1 Turning right, left, making U turn
2 Backing
3 Slowing or stopping
4 Going straight ahead
5 Starting in traffic lane or from parked position
6 Avoiding vehicle, object, pedestrian
7 Skidded before applying brakes
8 Skidded after applying brakes
9 Parked

67 Pedestrian Actions

Code the actions of the pedestrian just prior to the accident.

0 Not in roadway
1 Walking in roadway with traffic
2 Walking in roadway against traffic
3 Pushing or working on vehicle in roadway
4 Getting on or off vehicle
5 Standing in roadway
6 Other working in or on roadway
7 Playing in roadway
8 All other
9 Not stated
X Crossing or entering roadway not at intersection
R Crossing or entering roadway at intersection

68 Condition of Driver Reference Drinking

0 Not drinking
1 Had been drinking - obviously drunk
2 Had been drinking - ability impaired
3 Had been drinking - ability not impaired
4 Had been drinking - unknown if impaired
9 Not stated

69 Condition of Driver, Physical

X Apparently normal
0 Eyesight defective
1 Hearing defective
2 Other bodily defects
3 Illness
4 Fatigued
5 Apparently asleep

69 Condition of Driver, Physical

6 Attention diverted
7 Advanced senility
8 Other handicaps
9 Not stated

70 Condition of Pedestrian Reference Drinking

0 Not drinking
1 Had been drinking - obviously drunk
2 Had been drinking - ability impaired
3 Had been drinking - ability not impaired
4 Had been drinking - unknown if impaired
9 Not stated

71 Condition of Pedestrian, Physical

X Apparently normal
0 Eyesight defective
1 Hearing defective
2 Other bodily defects
3 Illness
4 Fatigued
5 apparently asleep
6 Attention diverted
7 Advanced senility
8 Other handicaps
9 Not stated

Columns 72 thru 80 must be coded from all accident reports

72 Traffic Control

This column indicates the type traffic control at the accident location.

0 Police officer
1 Automatic signal
2 Yield right of way sign
3 Center line marked
4 Other lane markings
5 Stop sign
6 Warning sign or signal
7 No passing zone
8 All others
9 Not stated

73 Character of Road - Horizontal

1 Straight road
2 Curve
9 Not stated

74 Character of Road - Vertical

1 Level road
2 On grade
3 Hillcrest
9 Not stated

75 Type of Road Surface

1 Concrete
2 Blacktop
3 Sand or dirt
4 Gravel
8 All other
9 Not stated

76 Condition of Road Surface

1 Dry
2 Wet
3 Snowy, icy
8 Other
9 Not stated

77 Weather Condition

1 Clear
2 Raining
3 Snowing
4 Fog
8 Other
9 Not stated

78 Light Condition

1 Daylight
2 Darkness
3 Dawn or dusk
9 Not stated

79 Kind of Locality

This column indicates the kind of locality in an area adjacent to the roadway within 300 feet of the accident location.

1 School or playground
2 Industrial or business

79 Kind of Locality

3 Residential
4 Open country
9 Not stated

80 Road Defects

1 Foreign material on surface of roadway
2 Loose sand, gravel, etc.
3 Holes, ruts, dips, bumps, etc.
4 Defective shoulders
5 Obstruction not lighted or signaled
6 Standing water, landslide, etc.
7 Obstructed by previous accident
8 All other defects
9 Not stated

APPENDIX B

1963 ADT VOLUMES AND TURNING MOVEMENTS

FOR INTERSECTIONS ON U. S. 52 BY-PASS

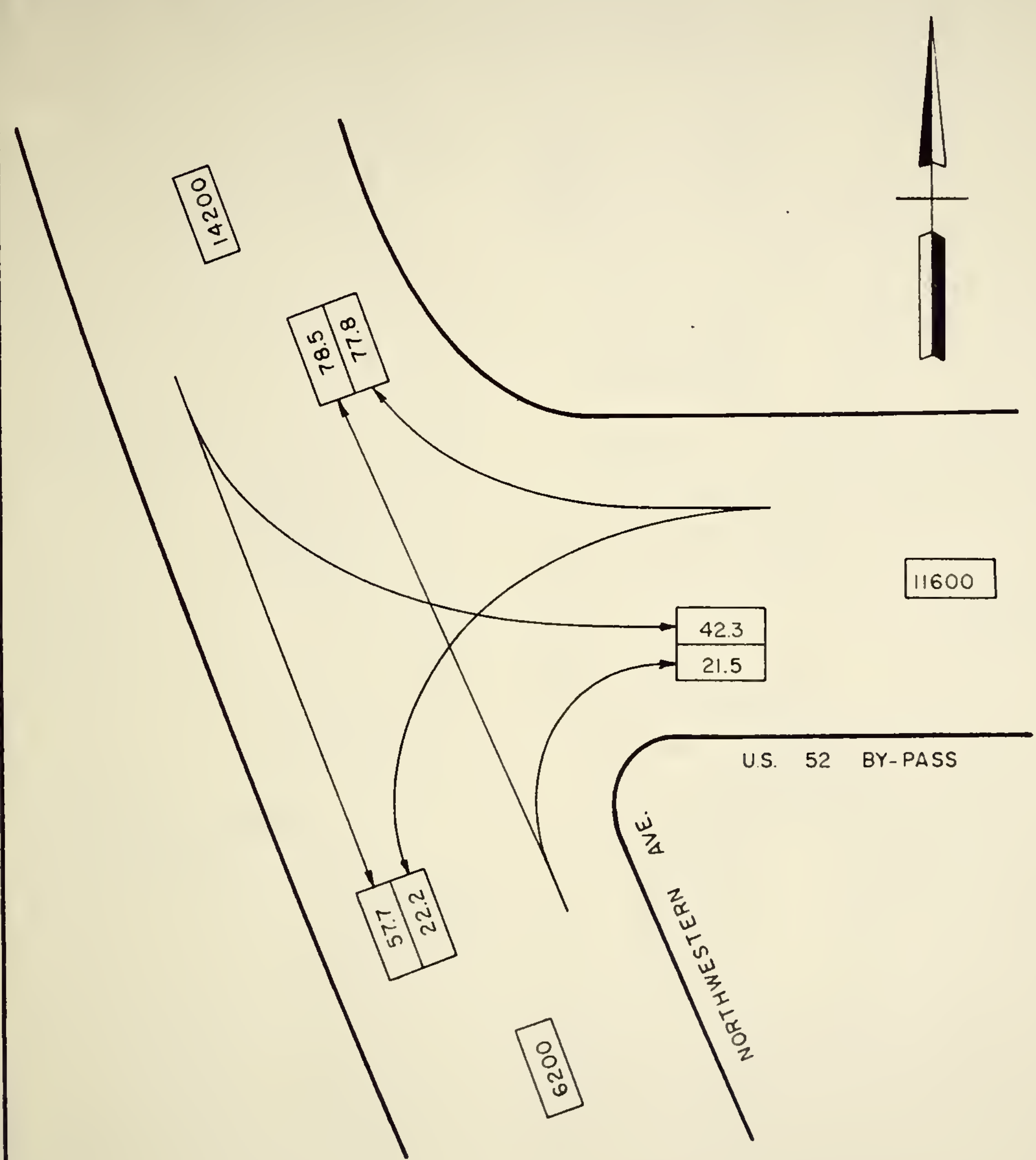


FIGURE 39 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND NORTHWESTERN AVE.

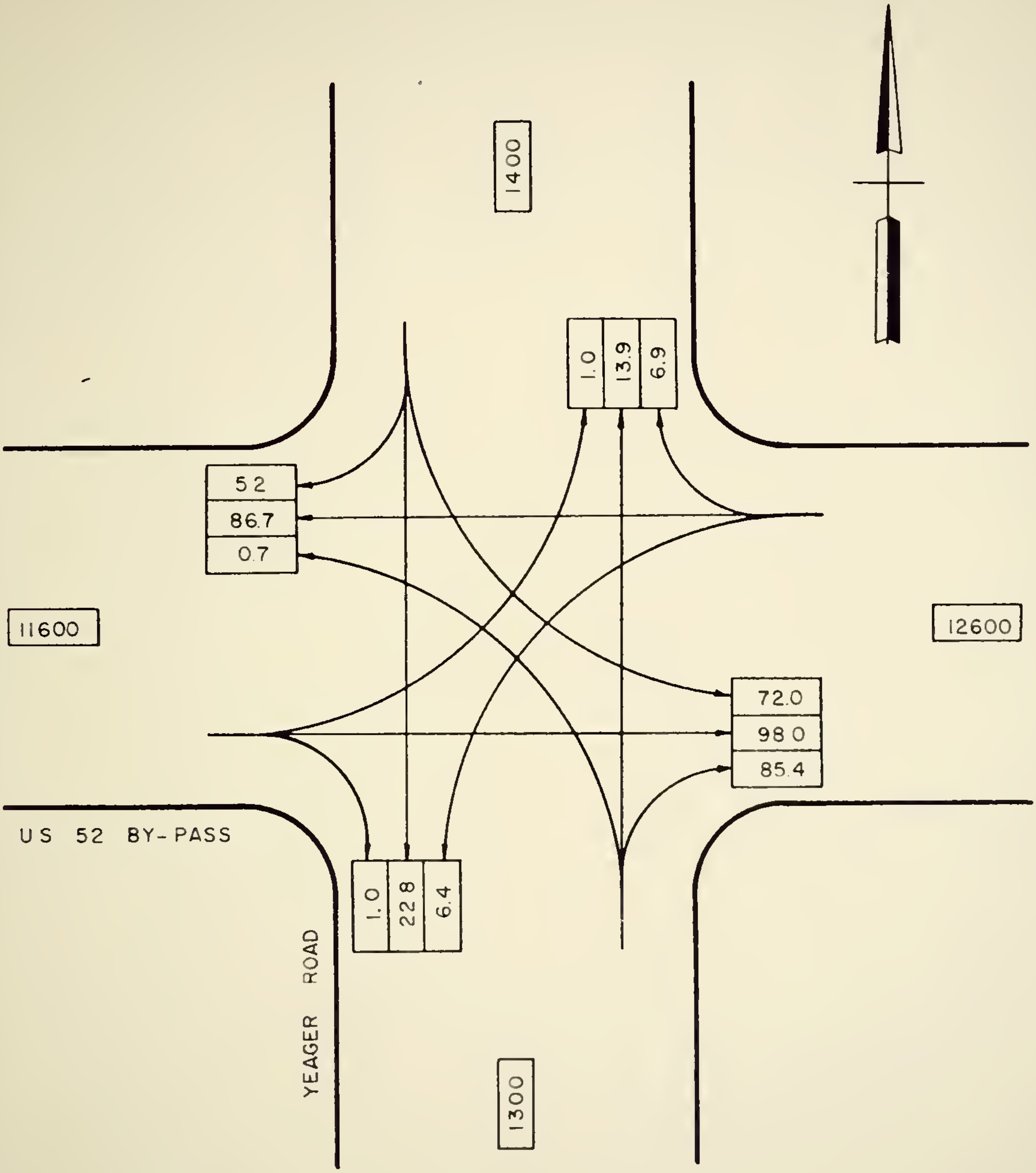


FIGURE 40 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND YEAGER ROAD.

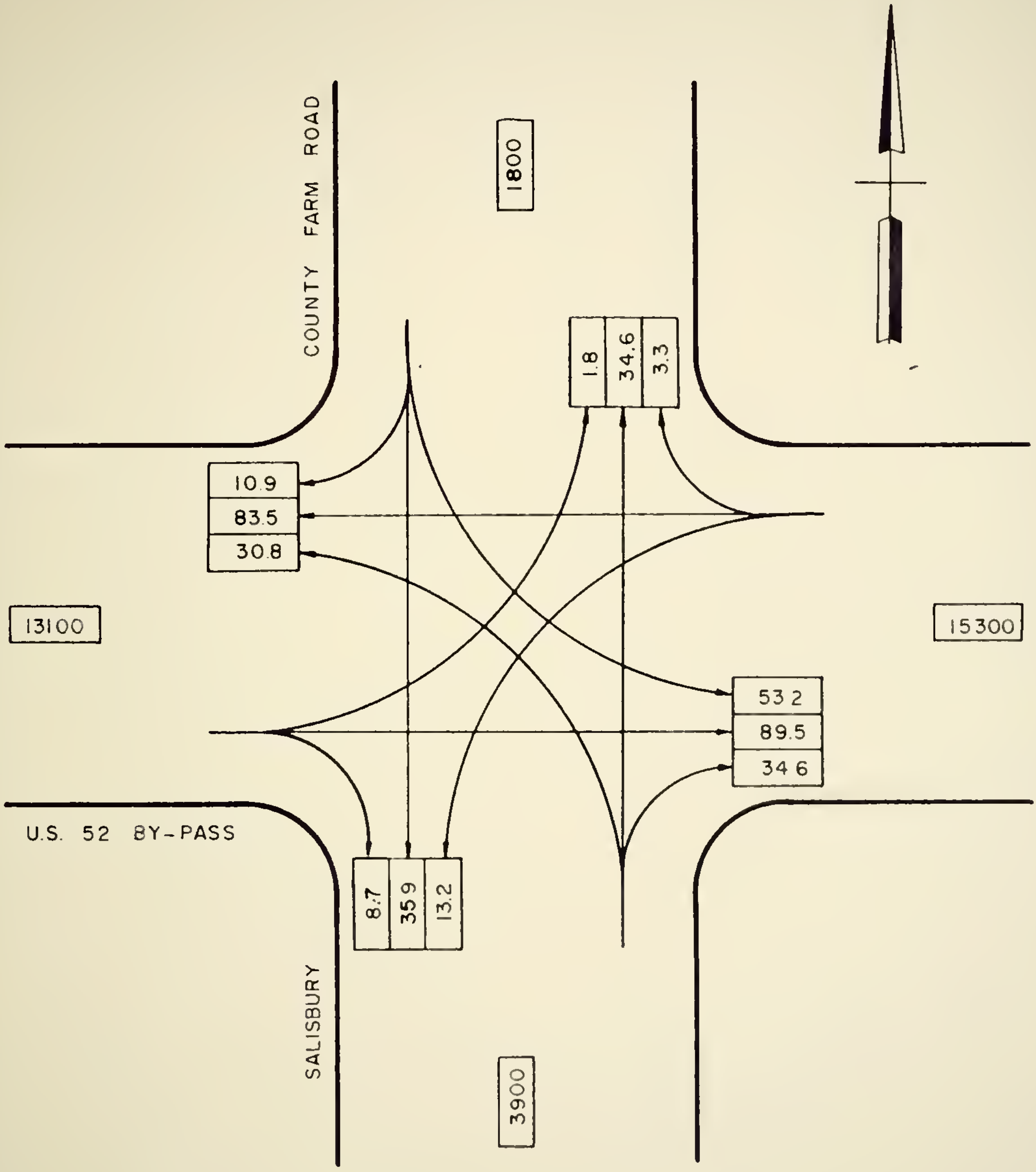


FIGURE 41 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND SALISBURY.

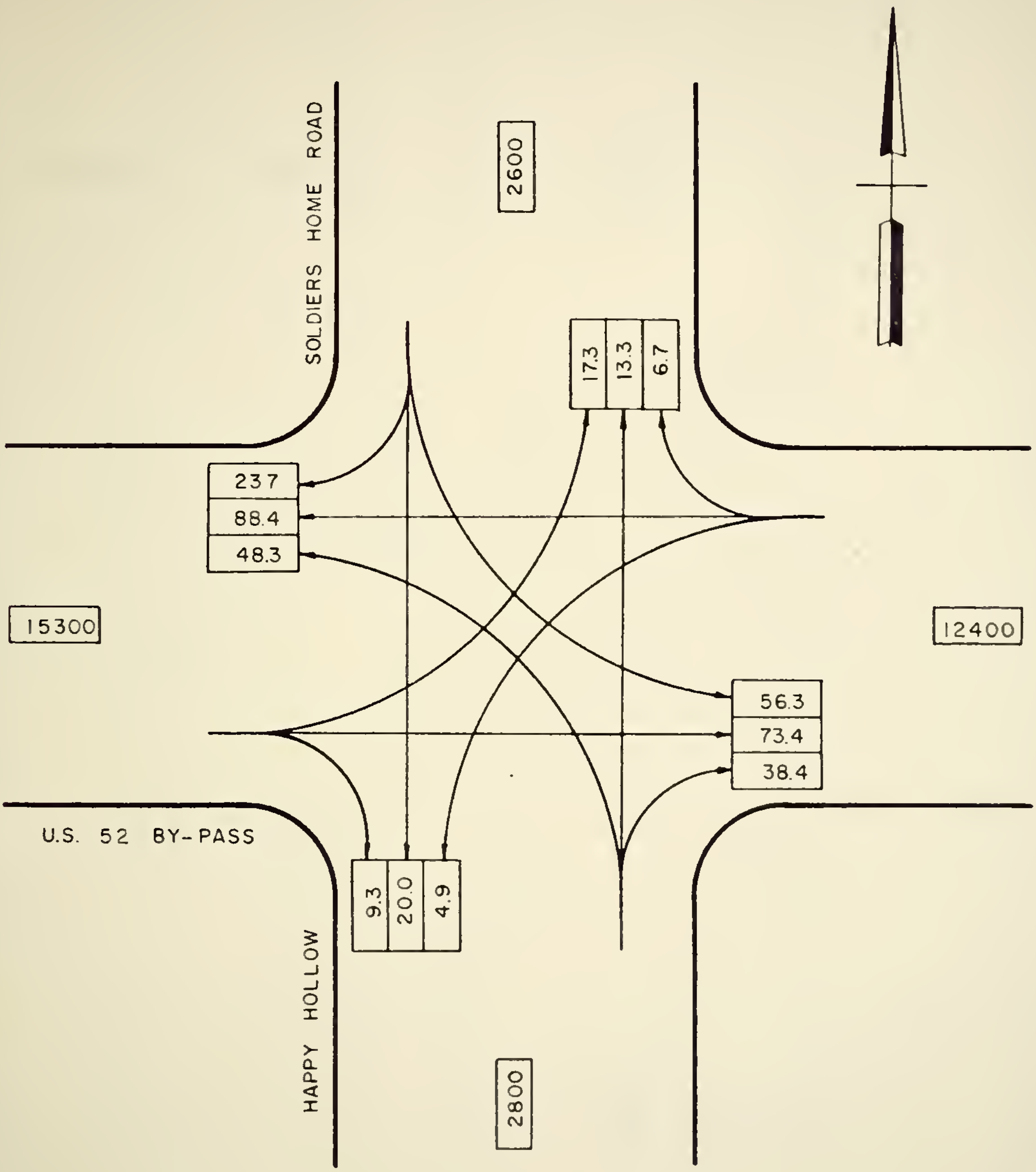


FIGURE 42 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND HAPPY HOLLOW.

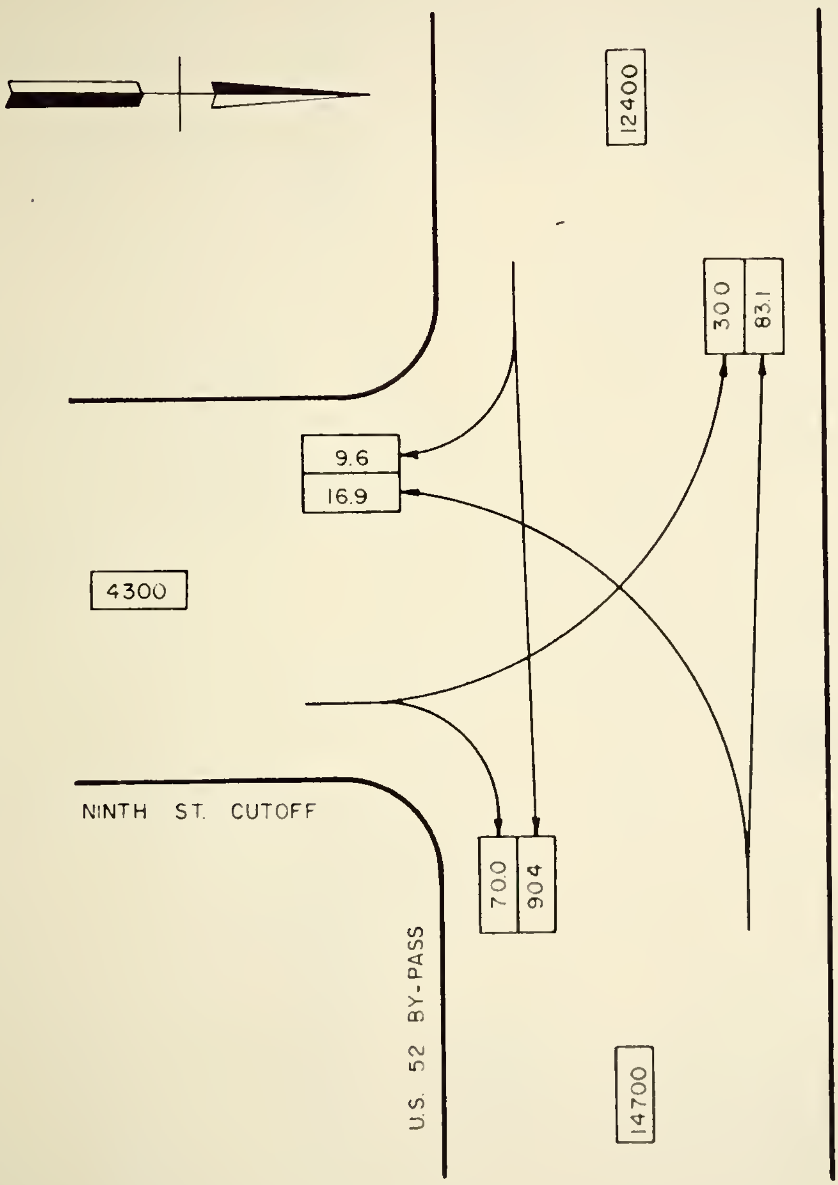


FIGURE 43 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND NINTH ST. CUTOFF.

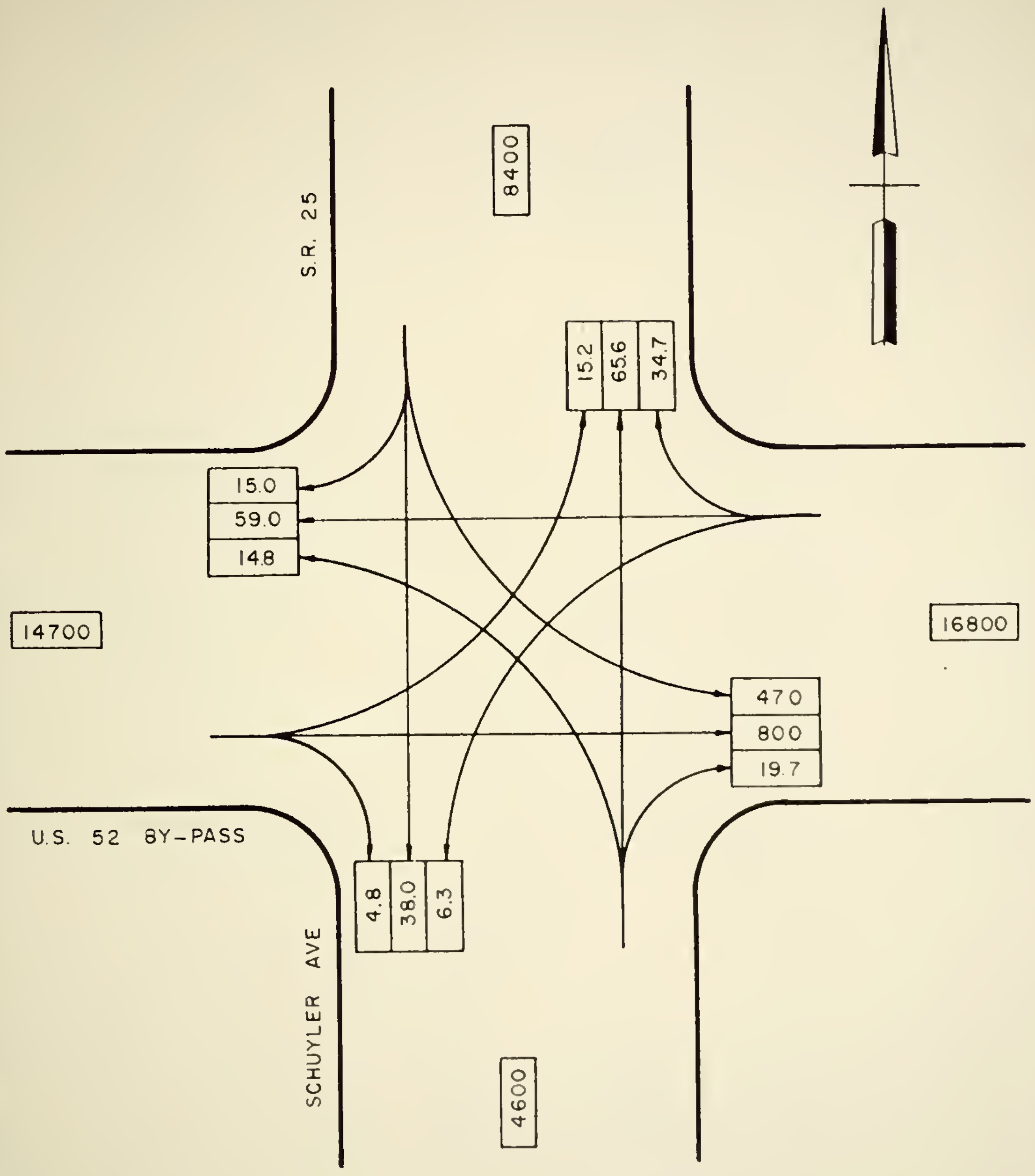


FIGURE 44 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND S.R. 25.

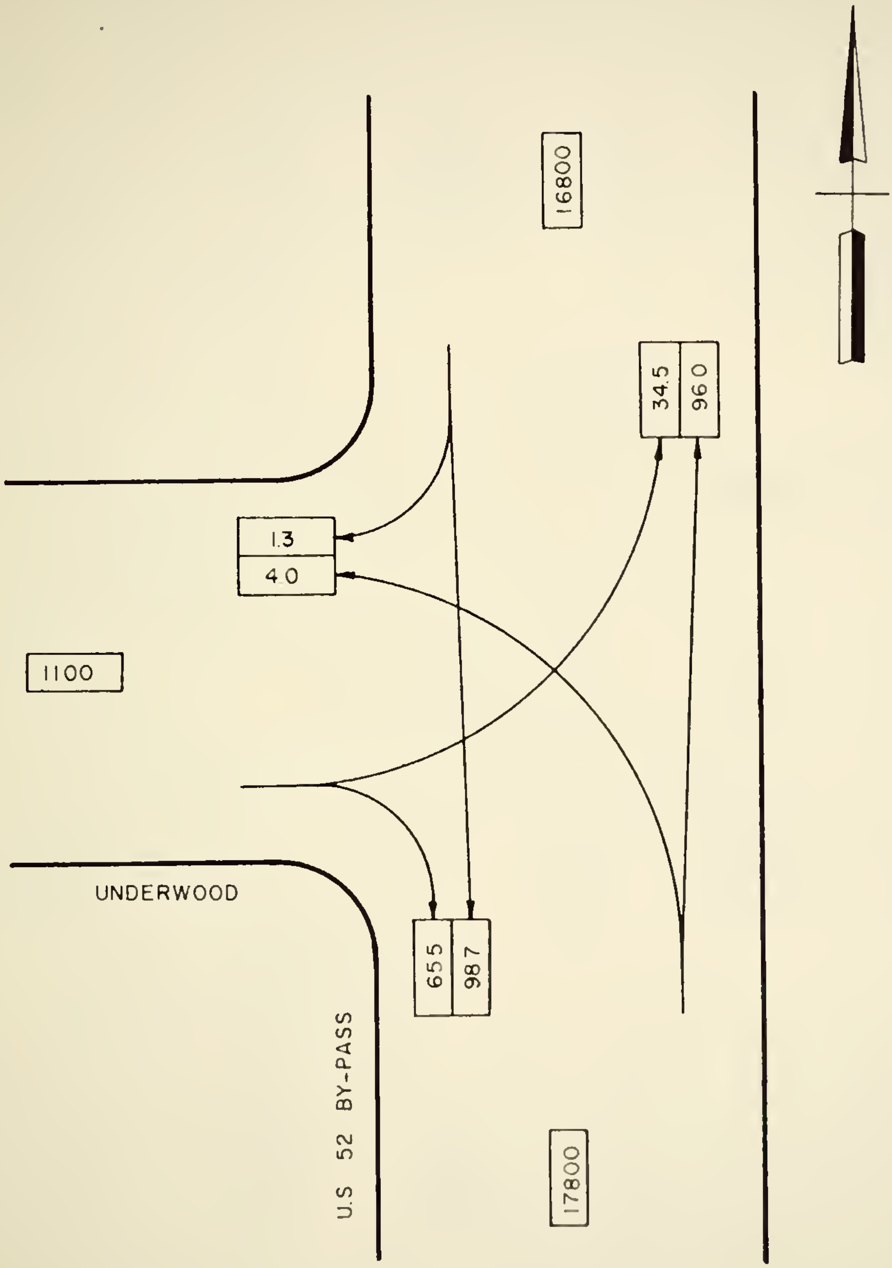


FIGURE 45 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND UNDERWOOD.

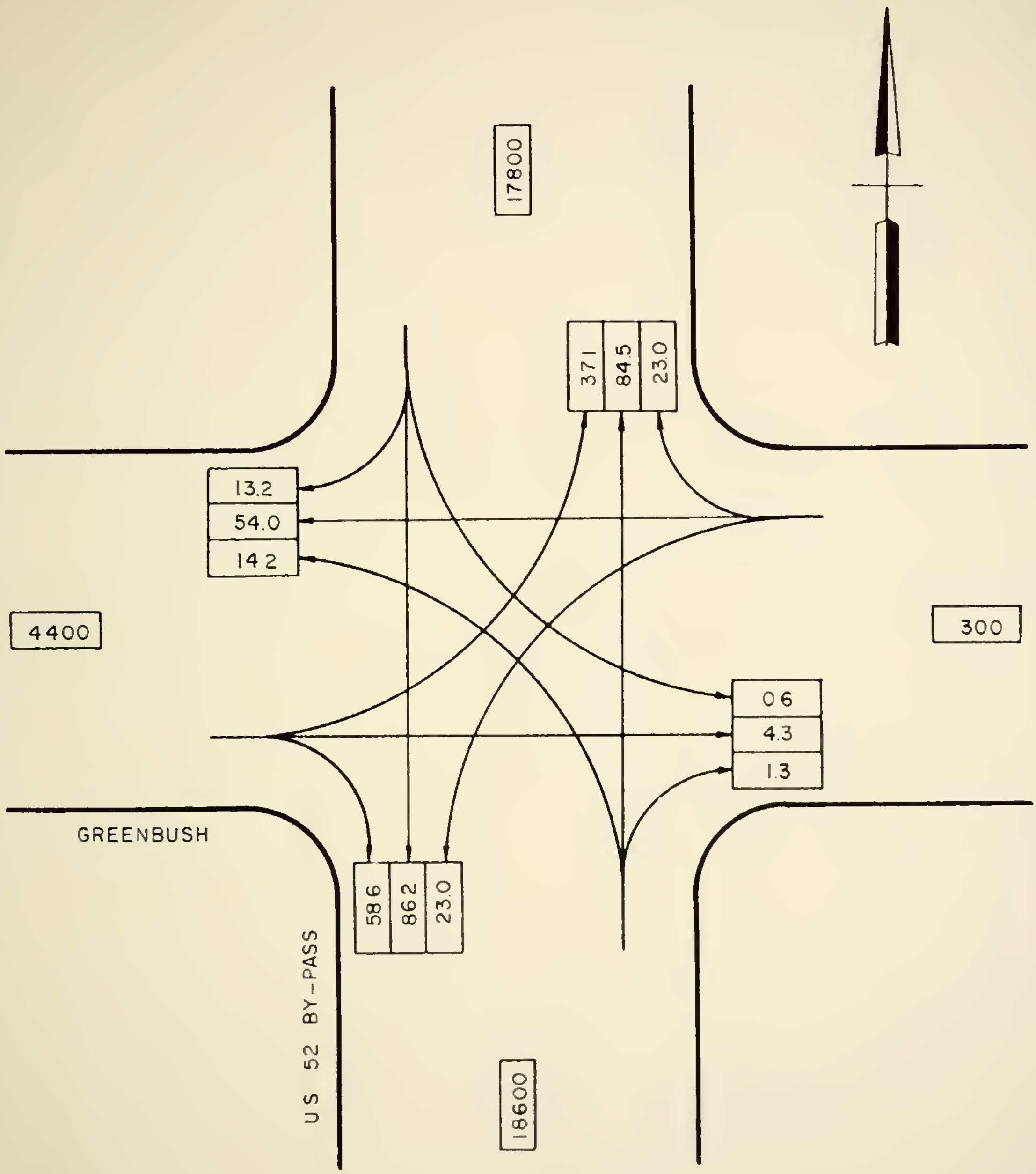


FIGURE 46 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND GREENBUSH.

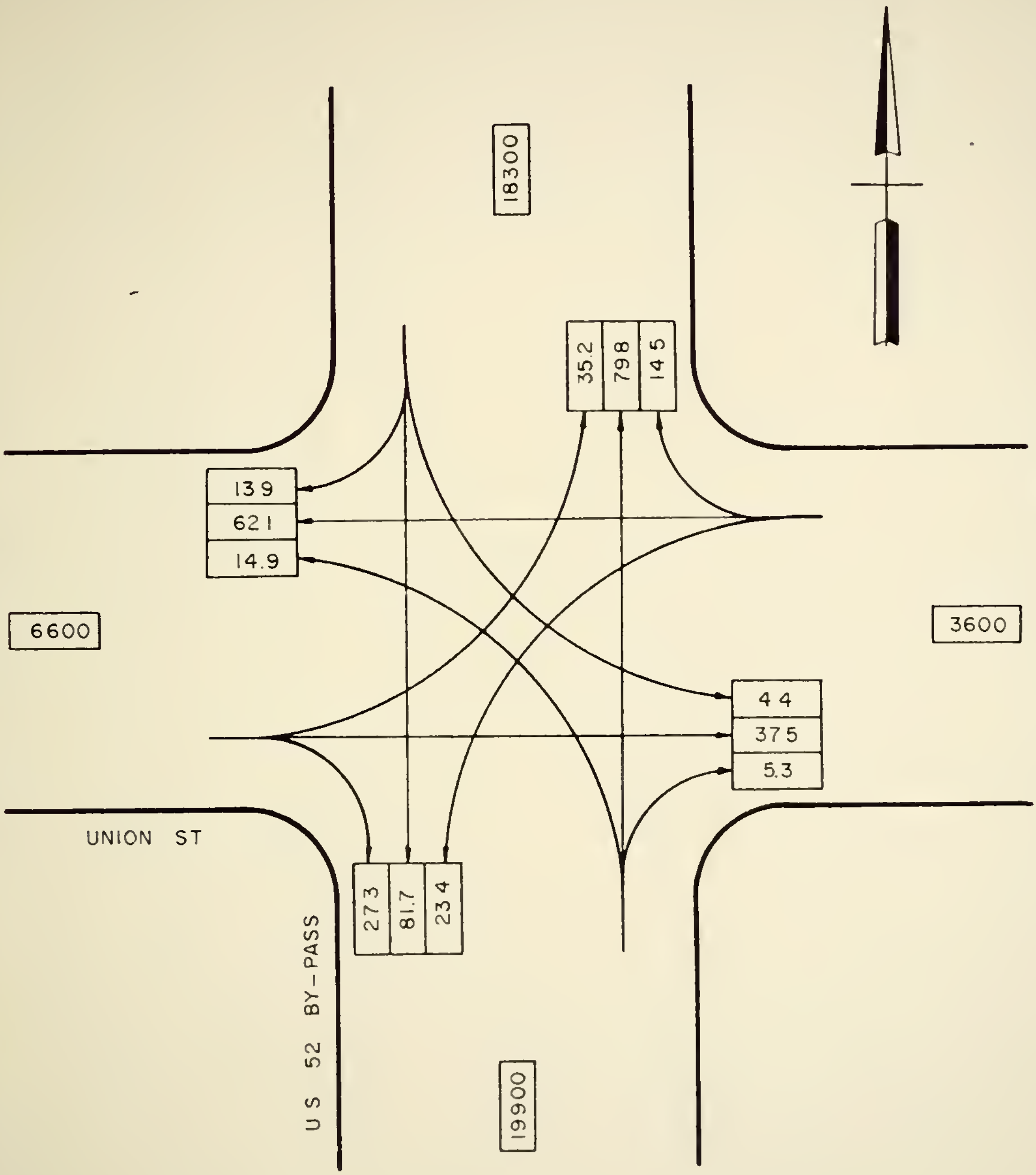


FIGURE 47 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND UNION ST..

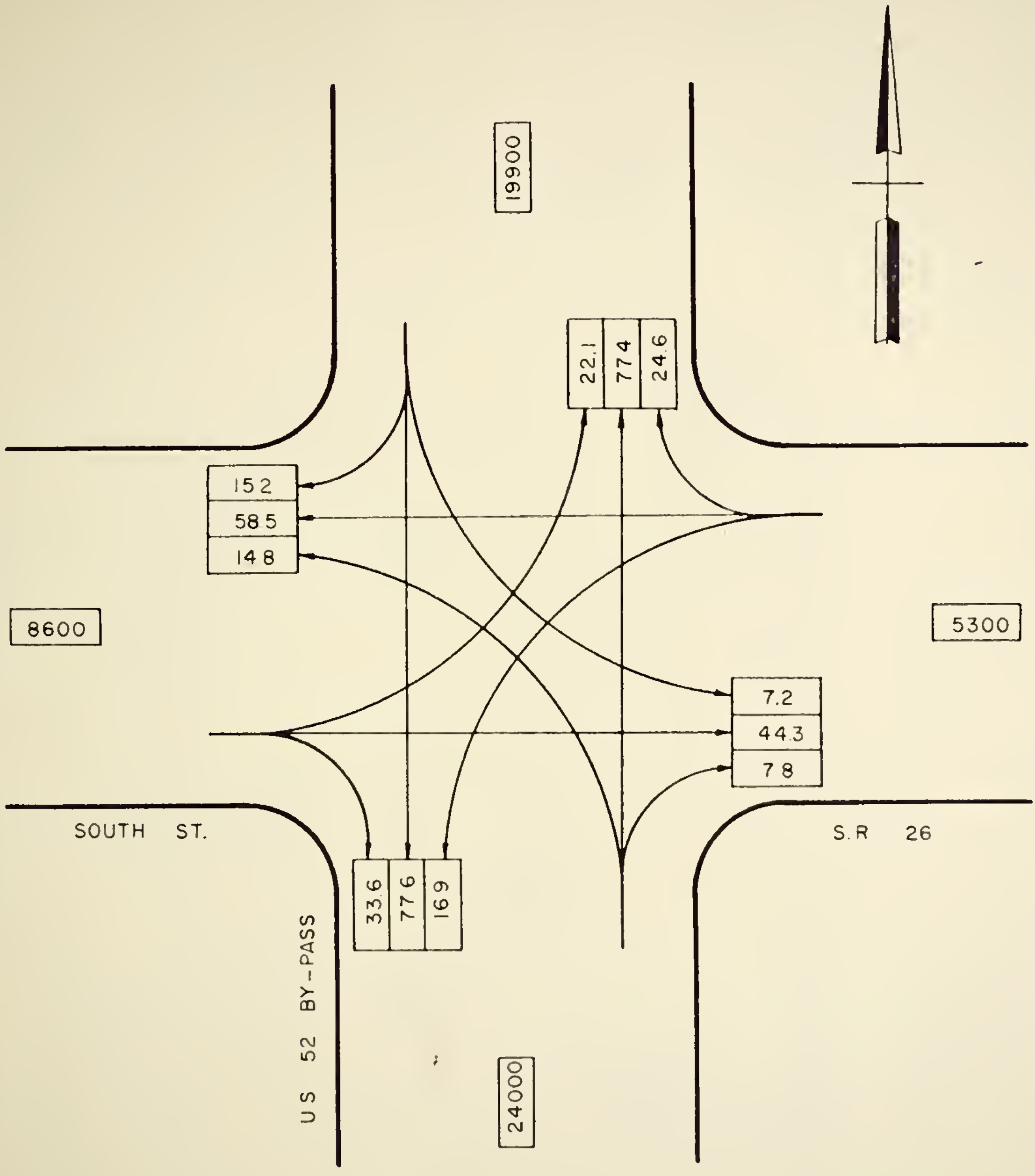


FIGURE 48 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND S.R. 26.

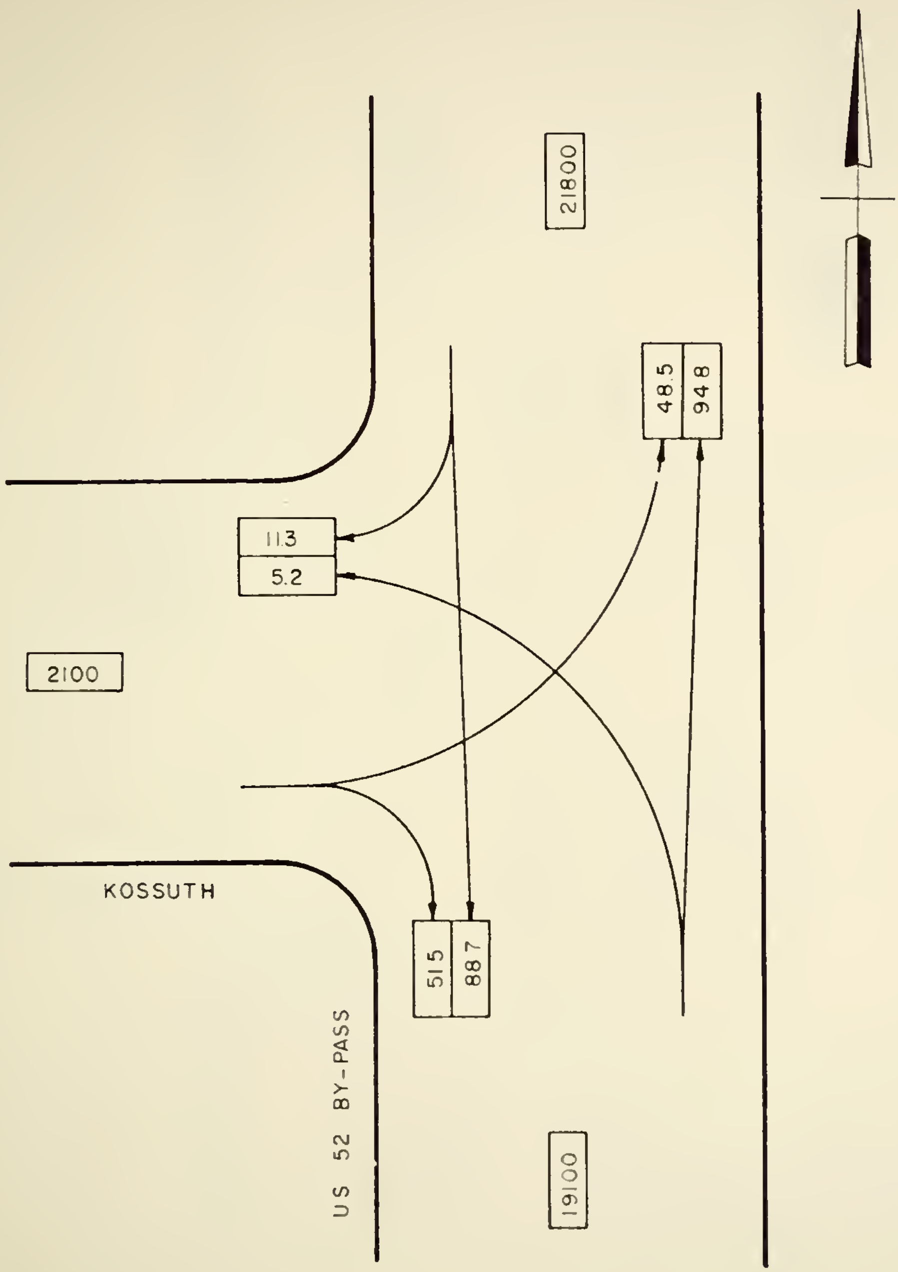


FIGURE 49 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND KOSSUTH.

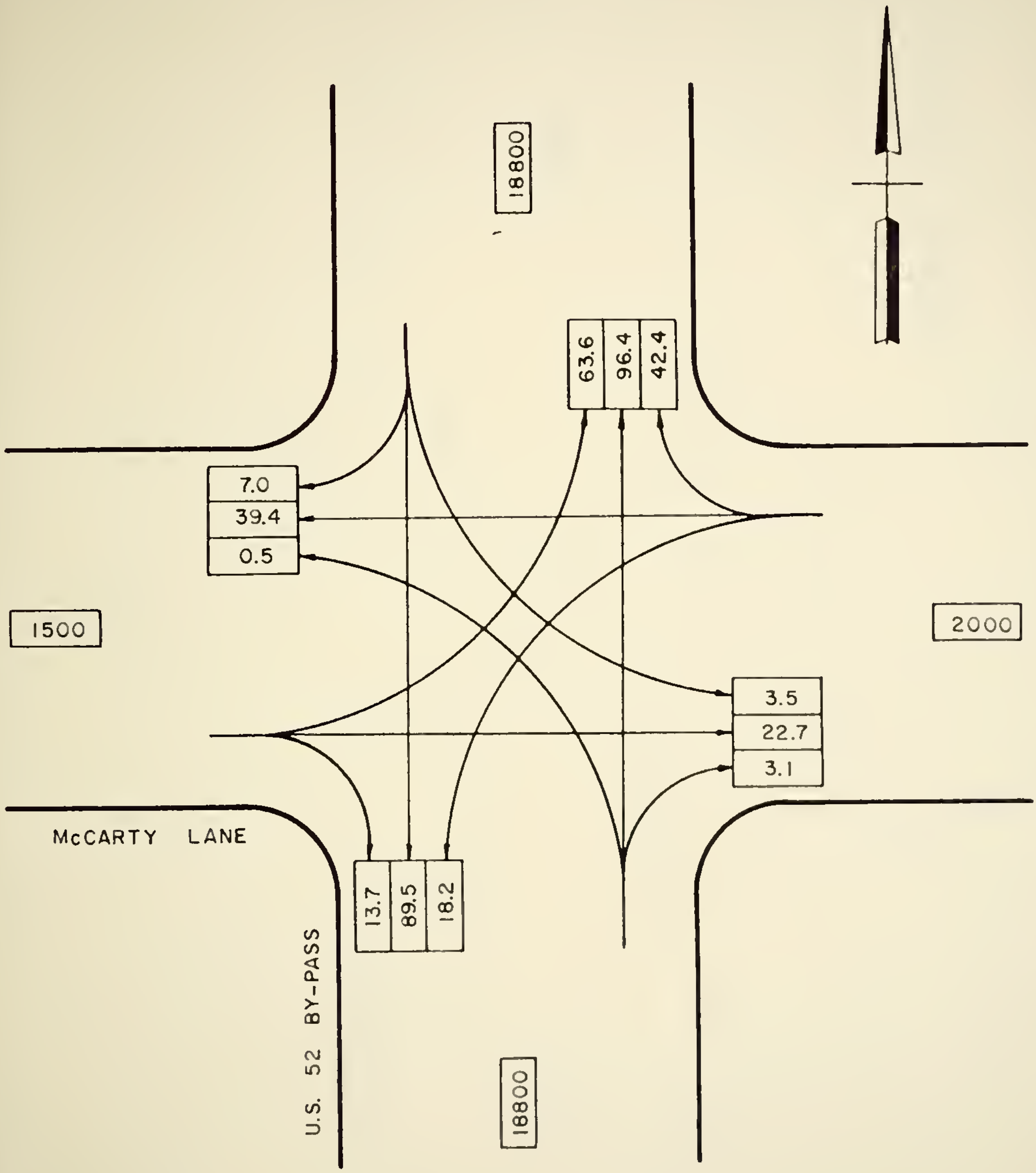


FIGURE 50 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND McCARTY LANE.

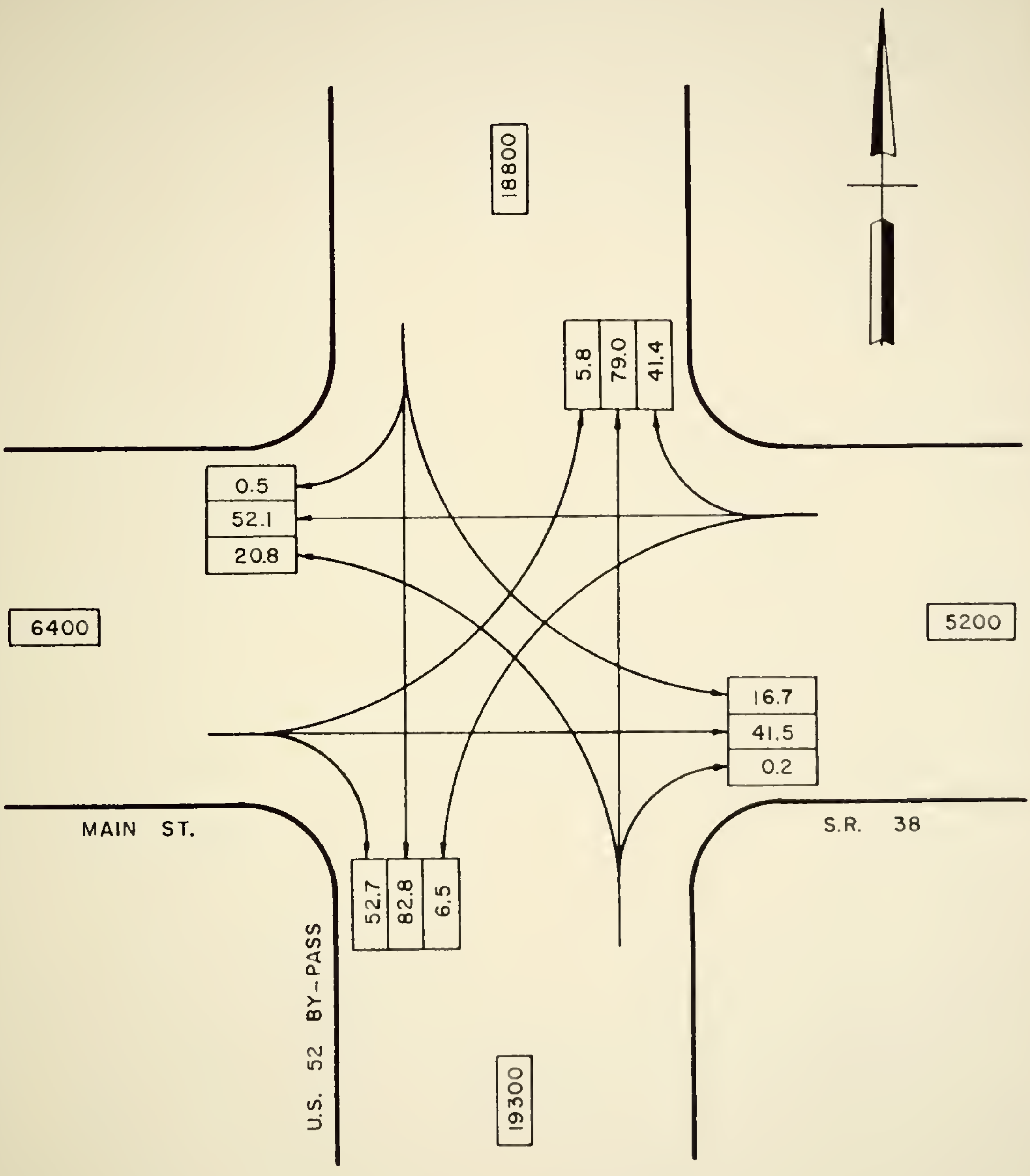


FIGURE 51 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND S.R. 38.

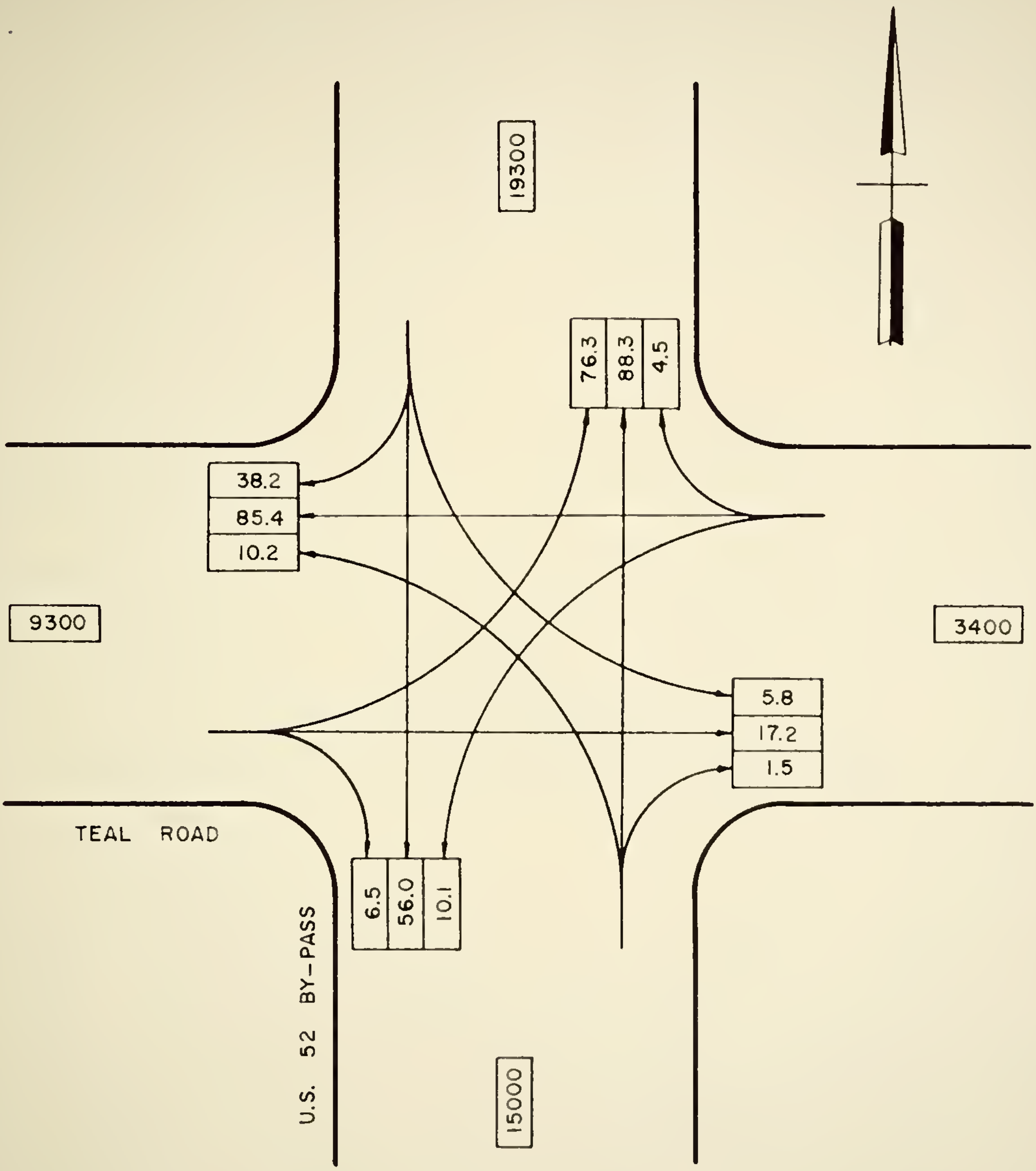


FIGURE 52 1963 ADT VOLUMES AND TURNING MOVEMENTS AT U.S. 52 BY-PASS AND TEAL ROAD.

APPENDIX C

COLLISION-CONDITION DIAGRAMS FOR

INTERSECTIONS ON U. S. 52 BY-PASS IN 1961, 1962, & 1963

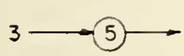
APPENDIX C

COLLISION-CONDITION DIAGRAMS FOR INTERSECTIONS ON U. S. 52 BY-PASS IN 1961, 1962, & 1963

The coding on the following collision-condition diagrams is as given in the following examples:

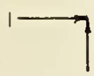
Example A:

Code — Meaning



Three rear end collisions in which a total of five persons were injured

Example B:

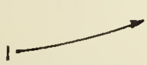


One right angle collision with no injuries

Example C:

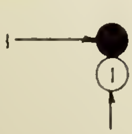
Two head-on collisions in which a total of one person was killed

Example D:



One single car accident with no injuries

Example E:



One right angle collision in which one person was injured and one person was killed.

Note: A circled number on the collision-condition diagrams with one or more arrows indicates the number of persons injured. A circled number without any arrows indicates a physical object as further defined in the legend of each Figure.

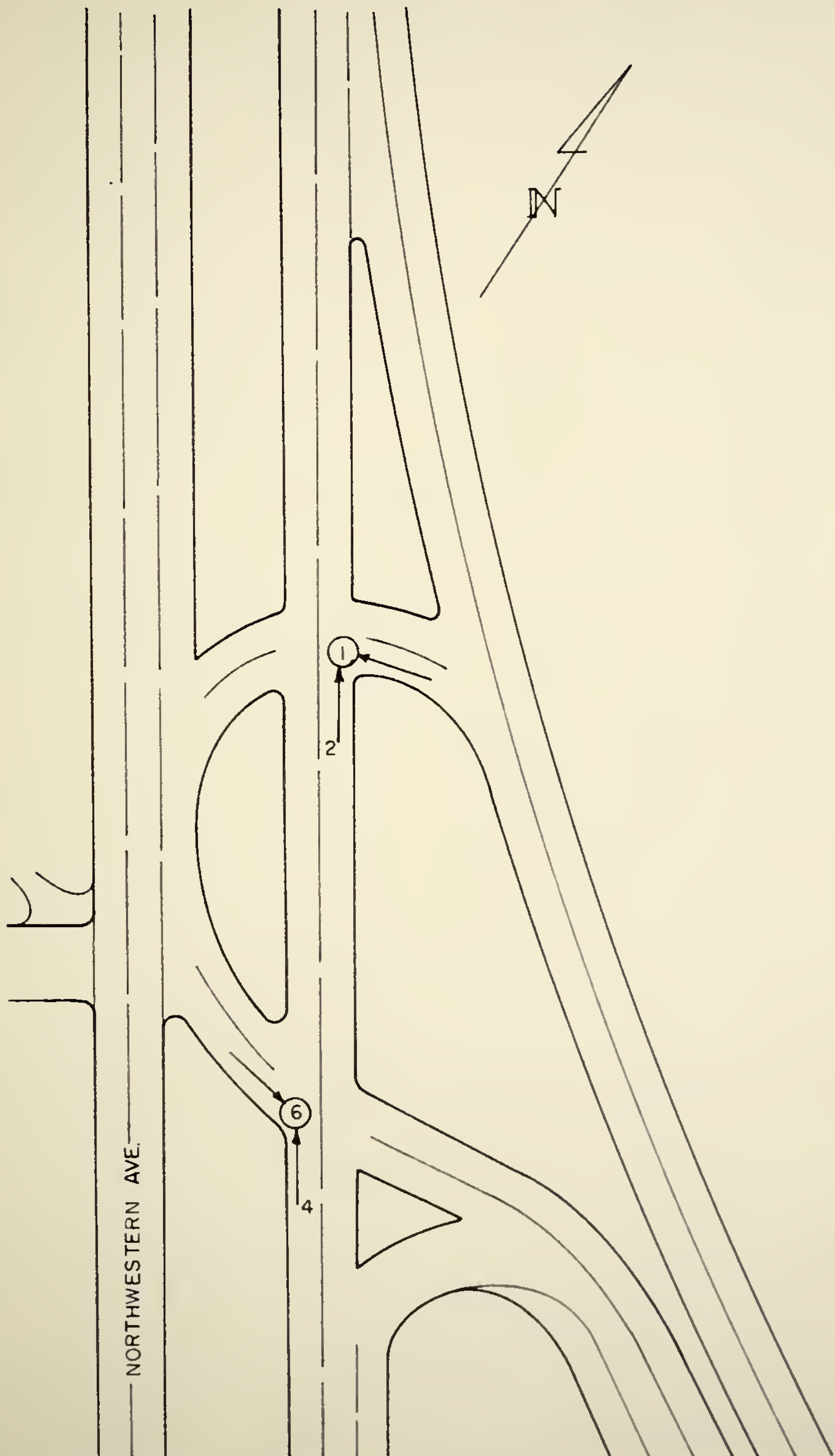


FIG. 53-U.S. 52 BY-PASS & NORTHWESTERN AVE.

1961

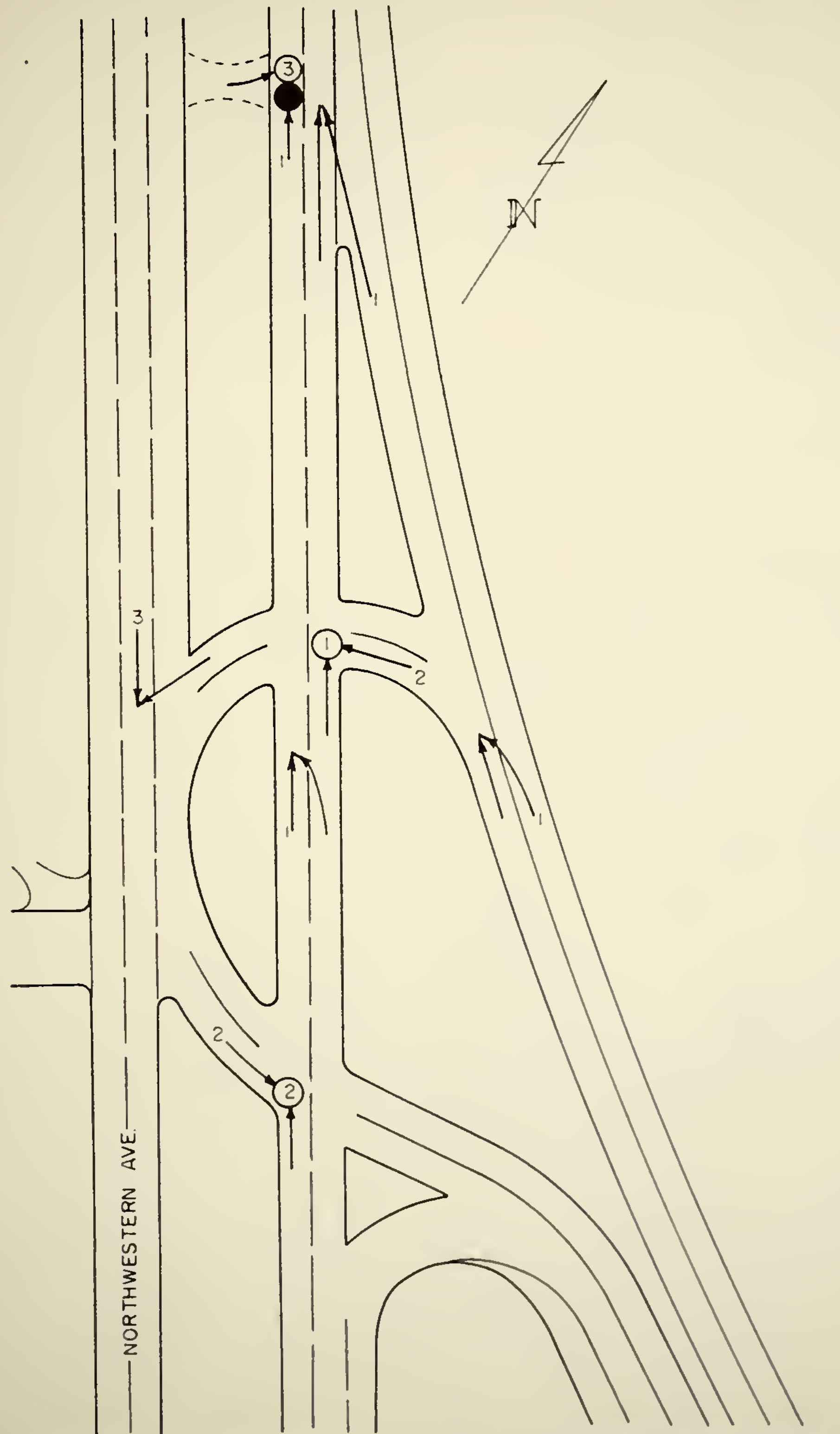


FIG. 54-U.S. 52 BY-PASS & NORTHWESTERN AVE.

1962

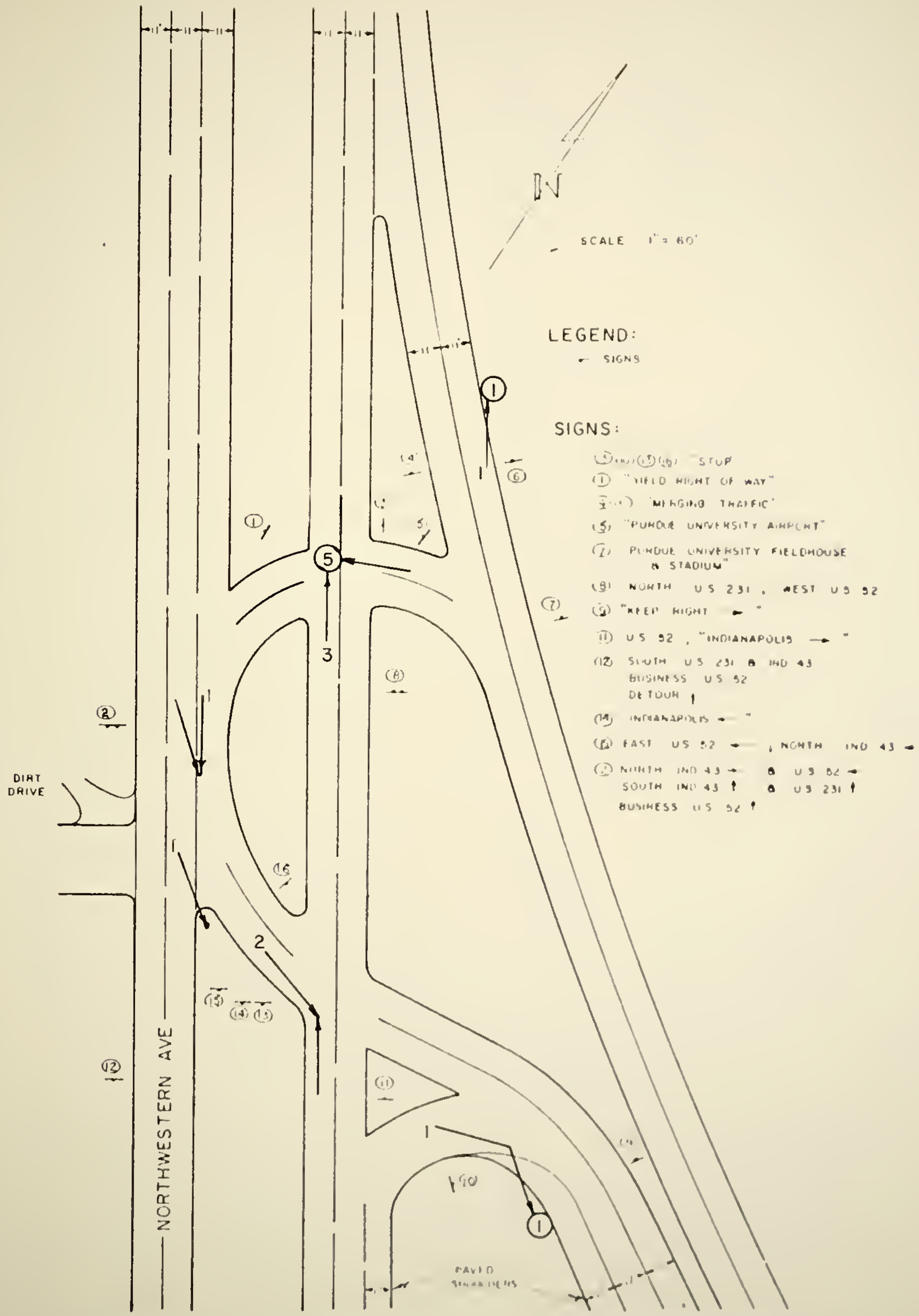


FIG. 55-U.S. 52 BY-PASS & NORTHWESTERN AVE.

1963

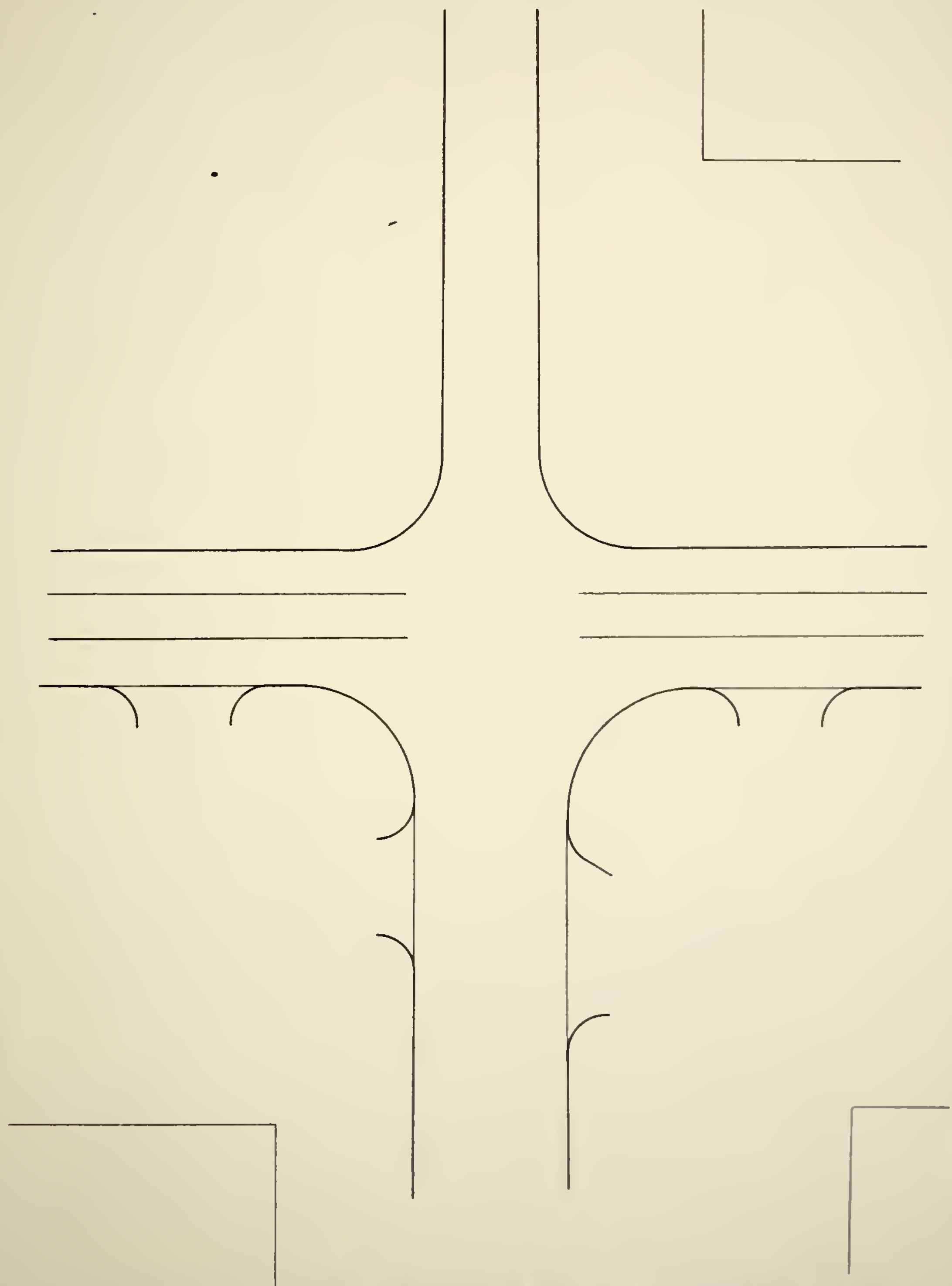


FIG. 56 - U.S. 52 BY-PASS & YEAGER ROAD

1961

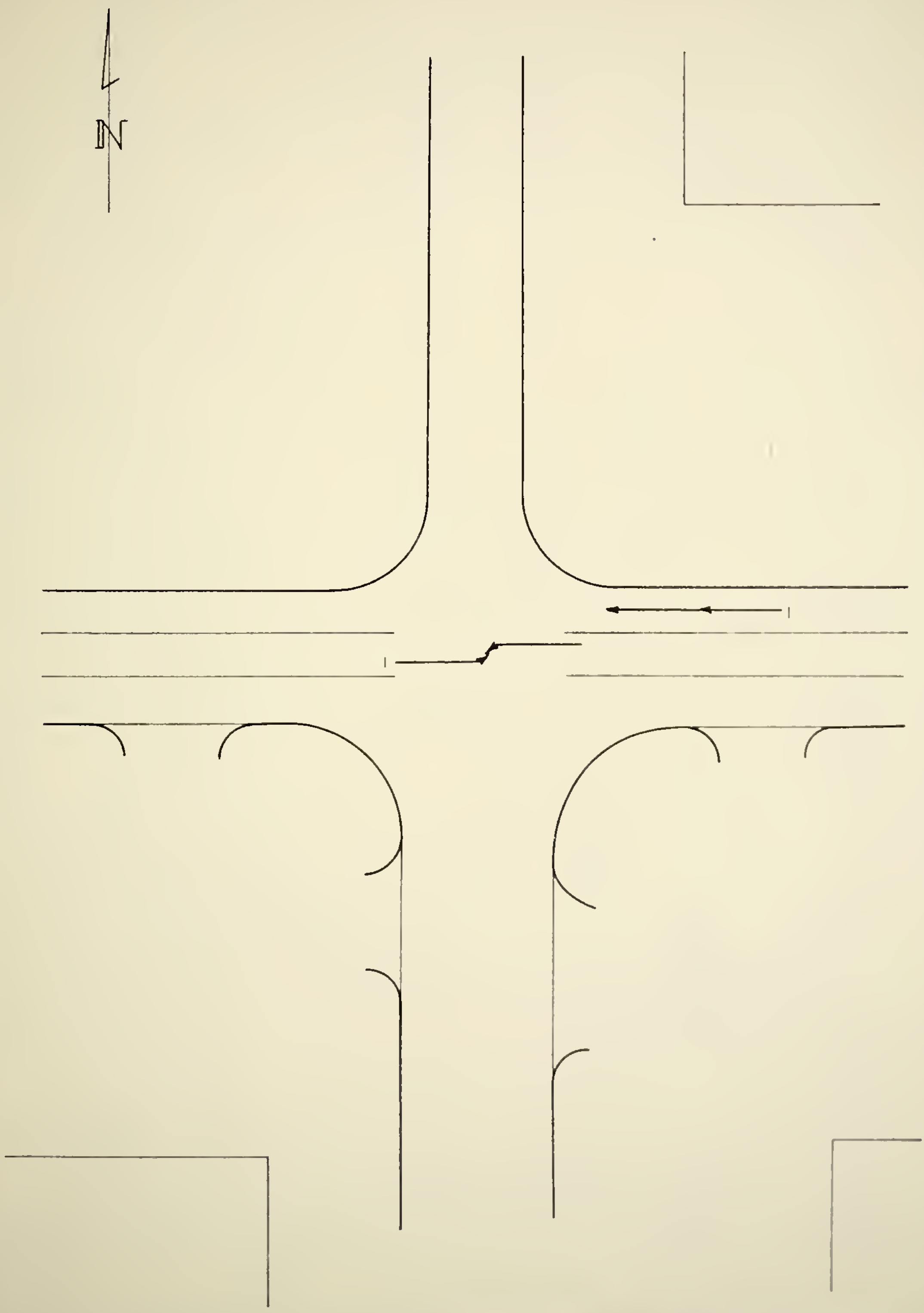


FIG. 57 - U.S. 52 BY-PASS & YEAGER ROAD

1962

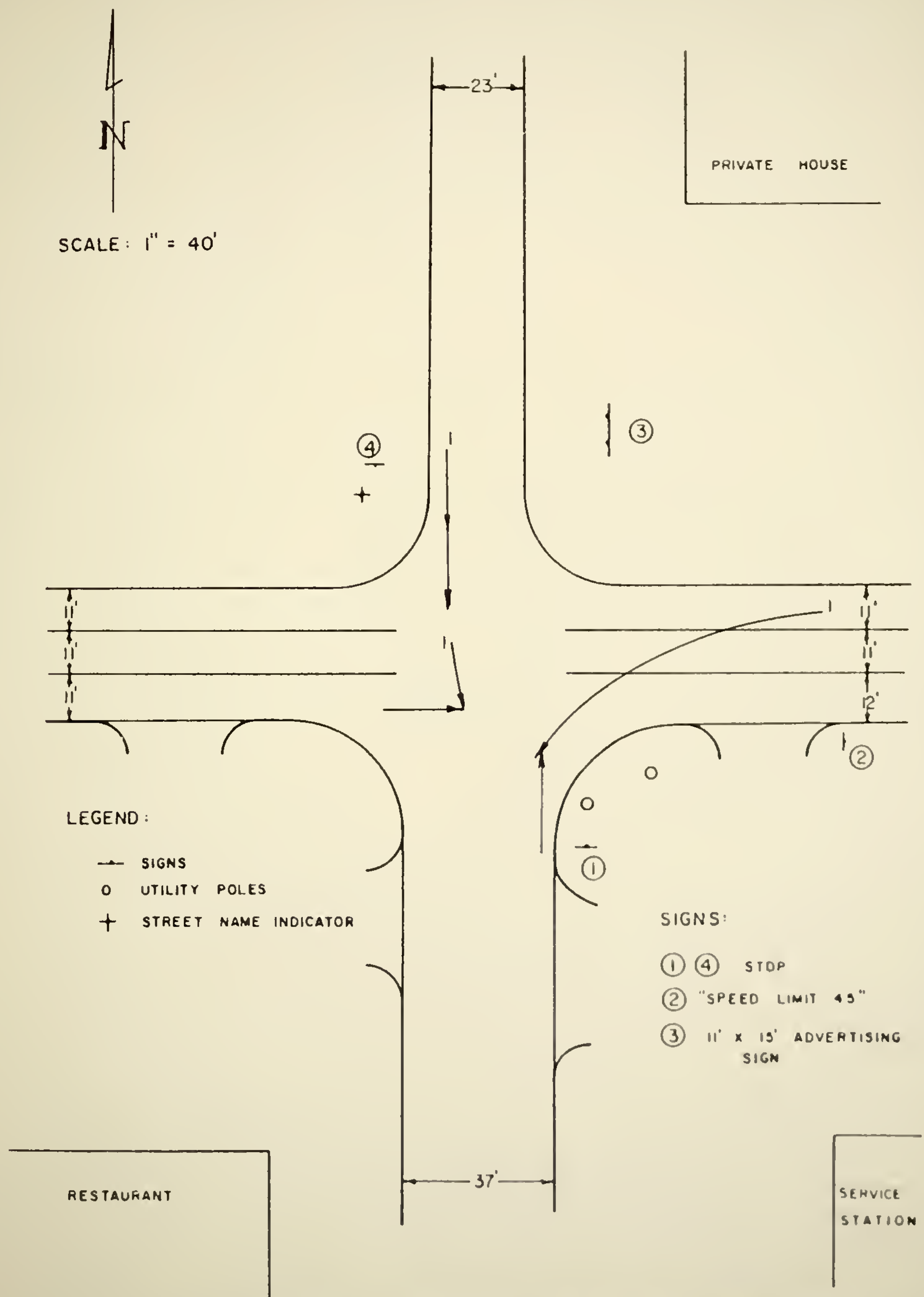


FIG. 58 - U.S. 52 BY-PASS & YEAGER ROAD

1963

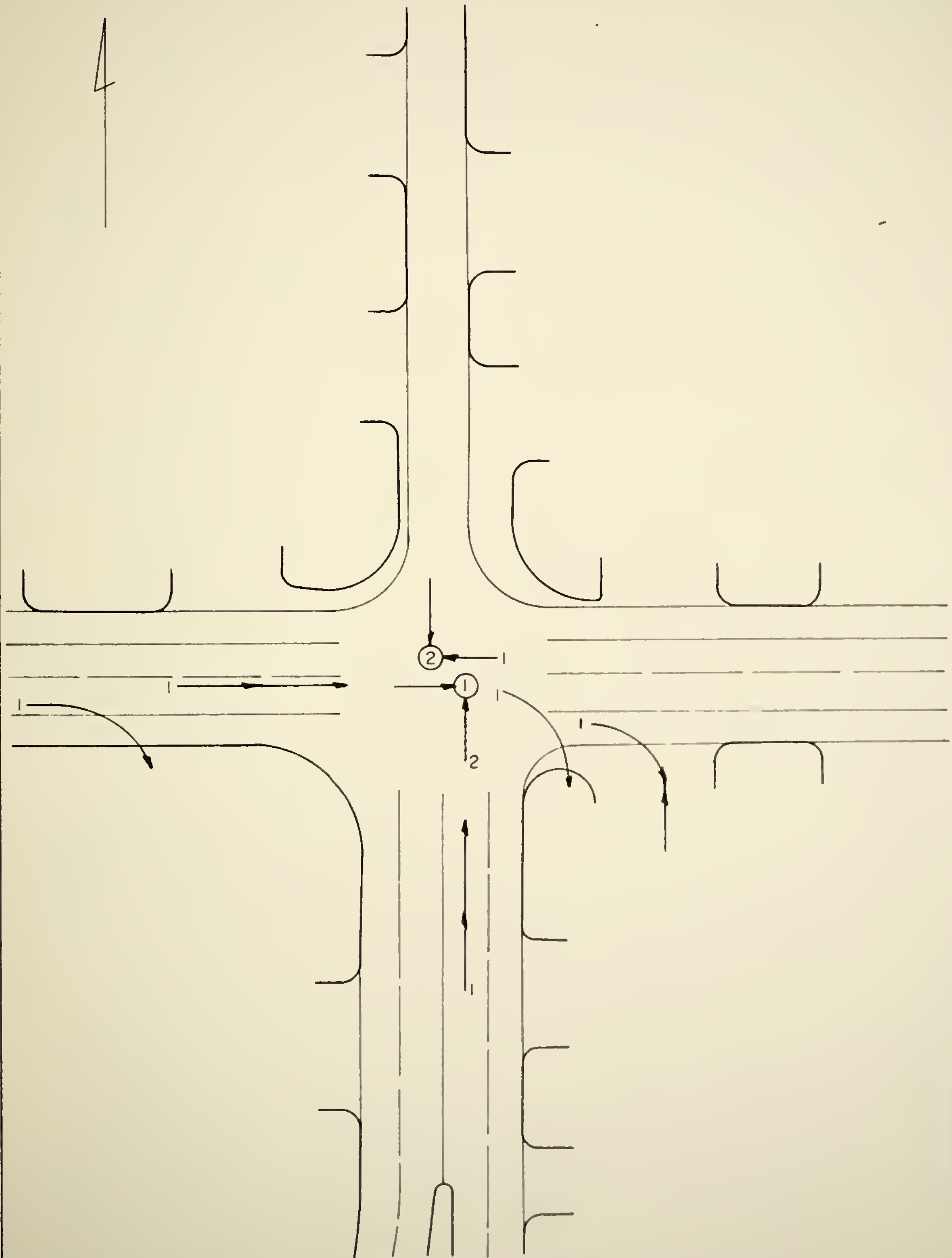


FIG. 59 - U.S. 52 BY-PASS & SALISBURY

1961

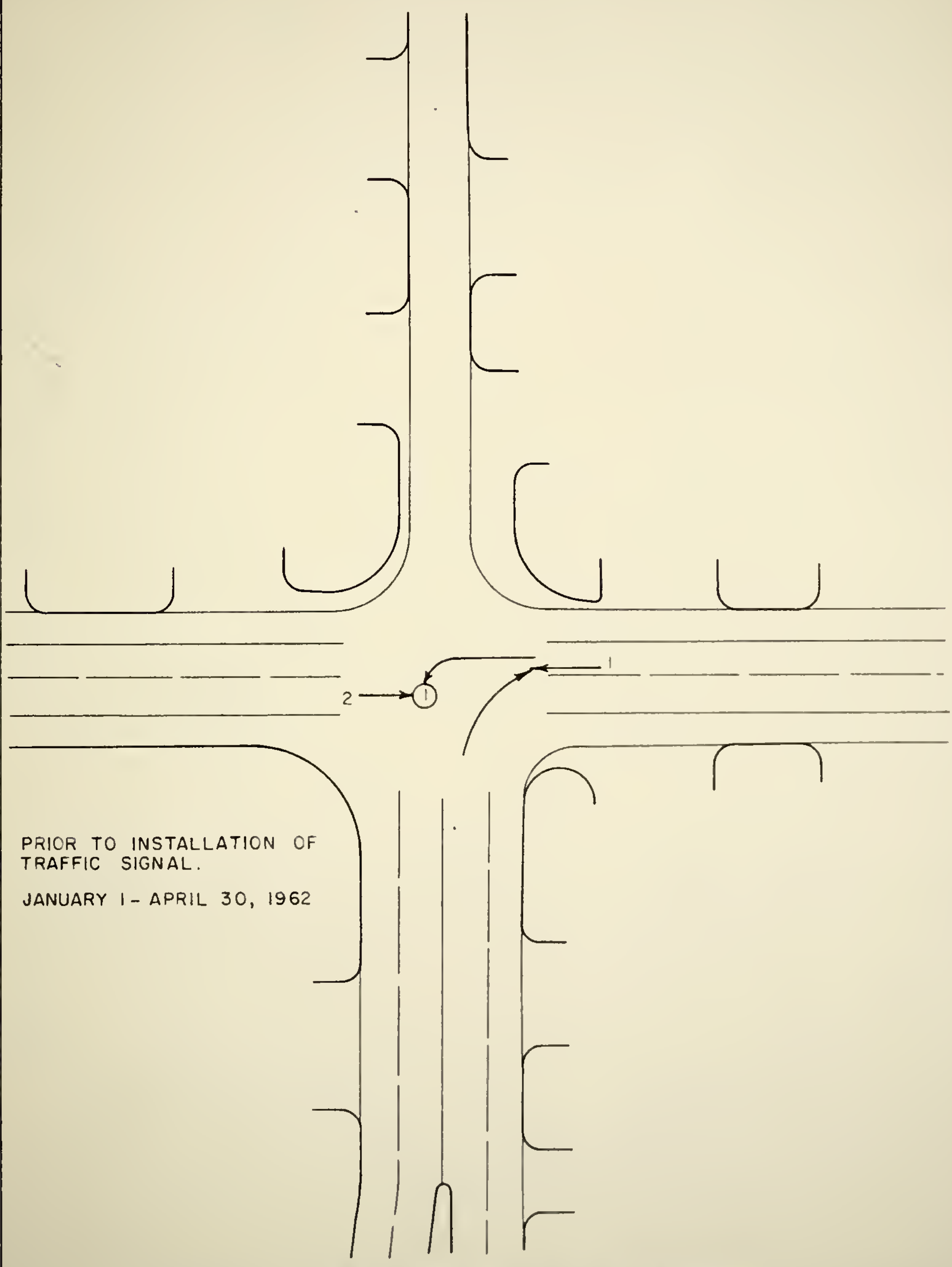


FIG. 60 - U.S. 52 BY-PASS & SALISBURY

1962 A

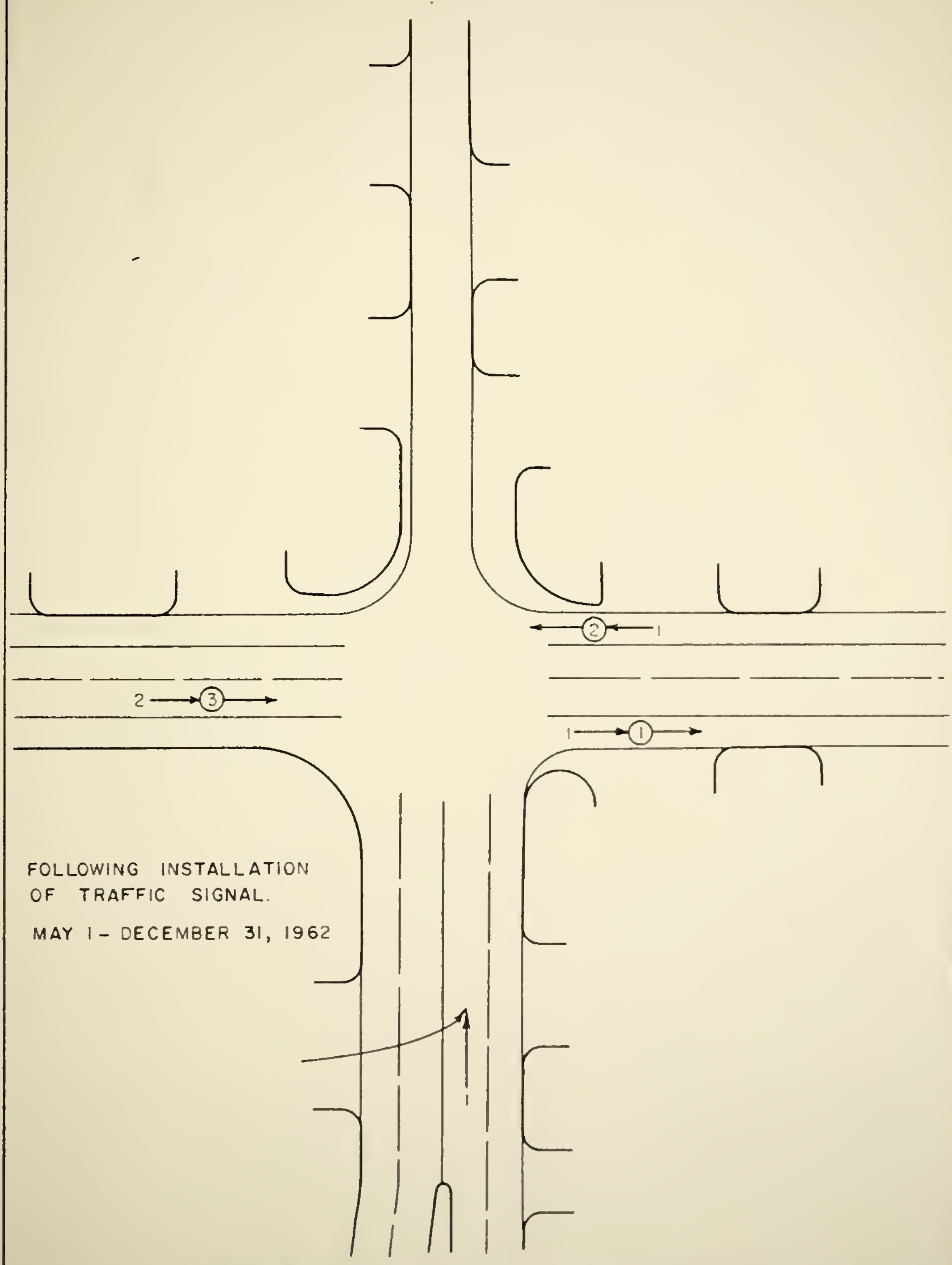


FIG. 61 - U.S. 52 BY-PASS & SALISBURY

1962 B

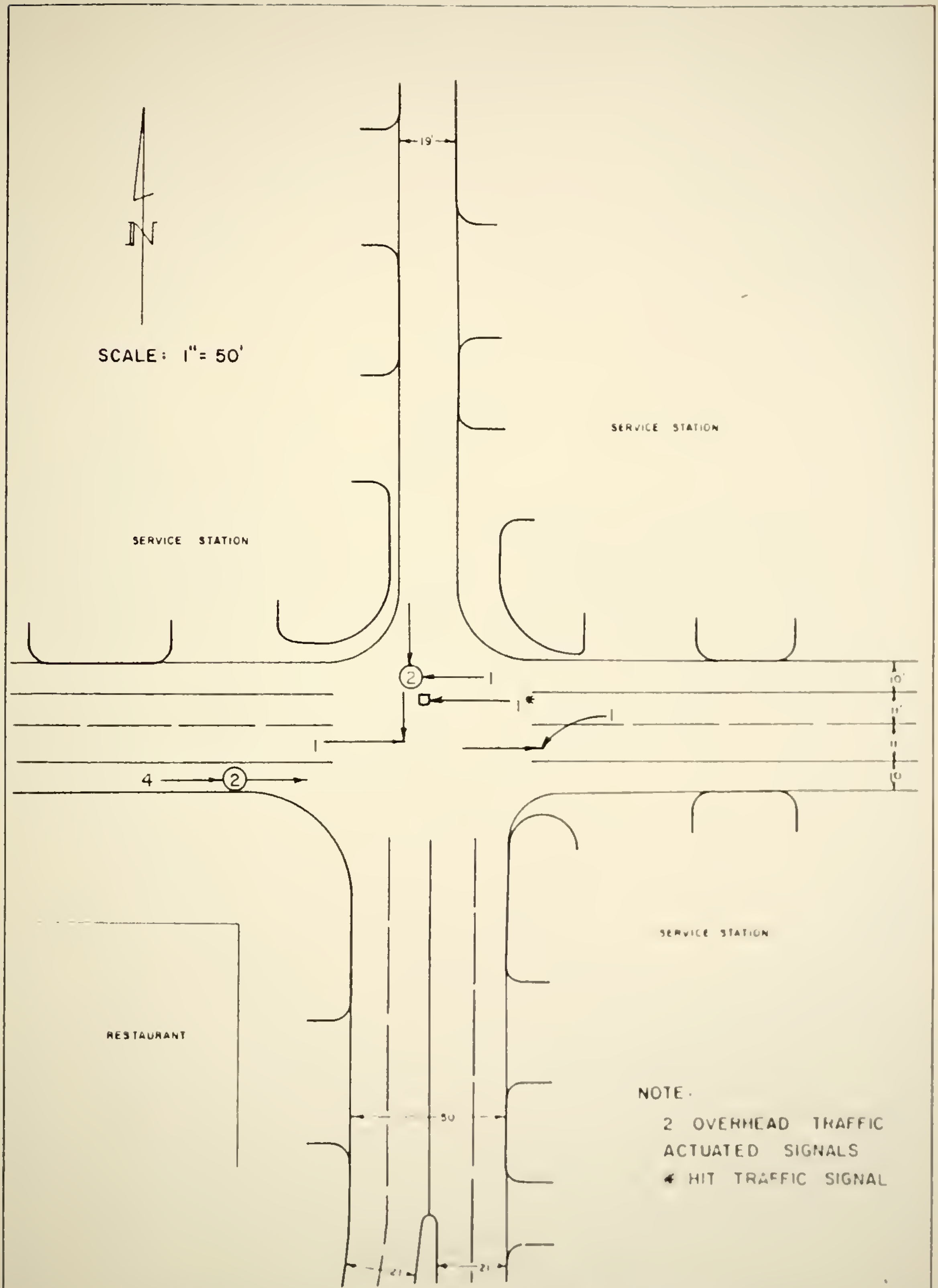


FIG. 62 - U.S. 52 BY-PASS & SALISBURY

1963

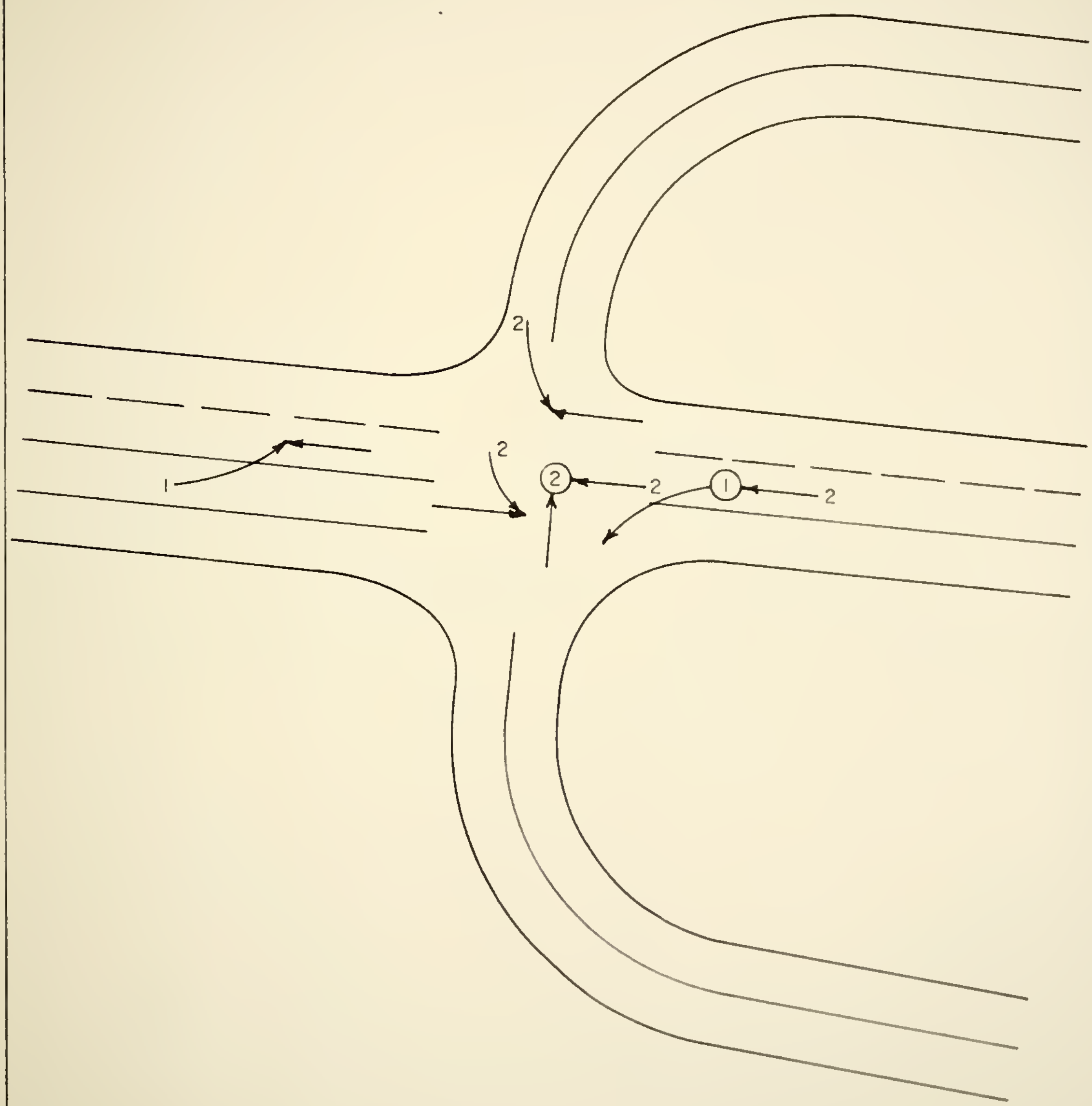


FIG. 63 – U.S. 52 BY-PASS & HAPPY HOLLOW

1961

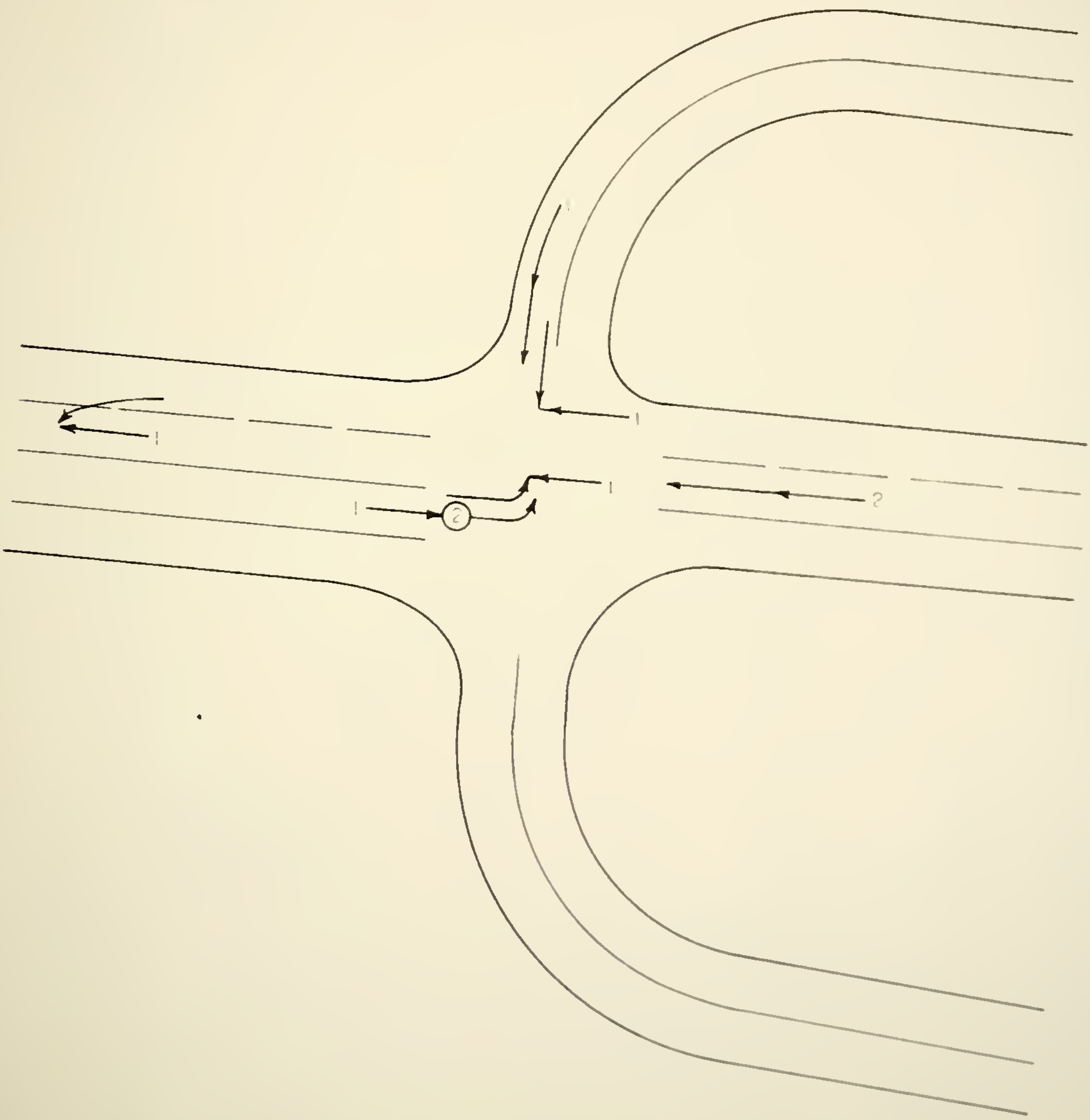


FIG. 64 - U.S. 52 BY-PASS & HAPPY HOLLOW

1962

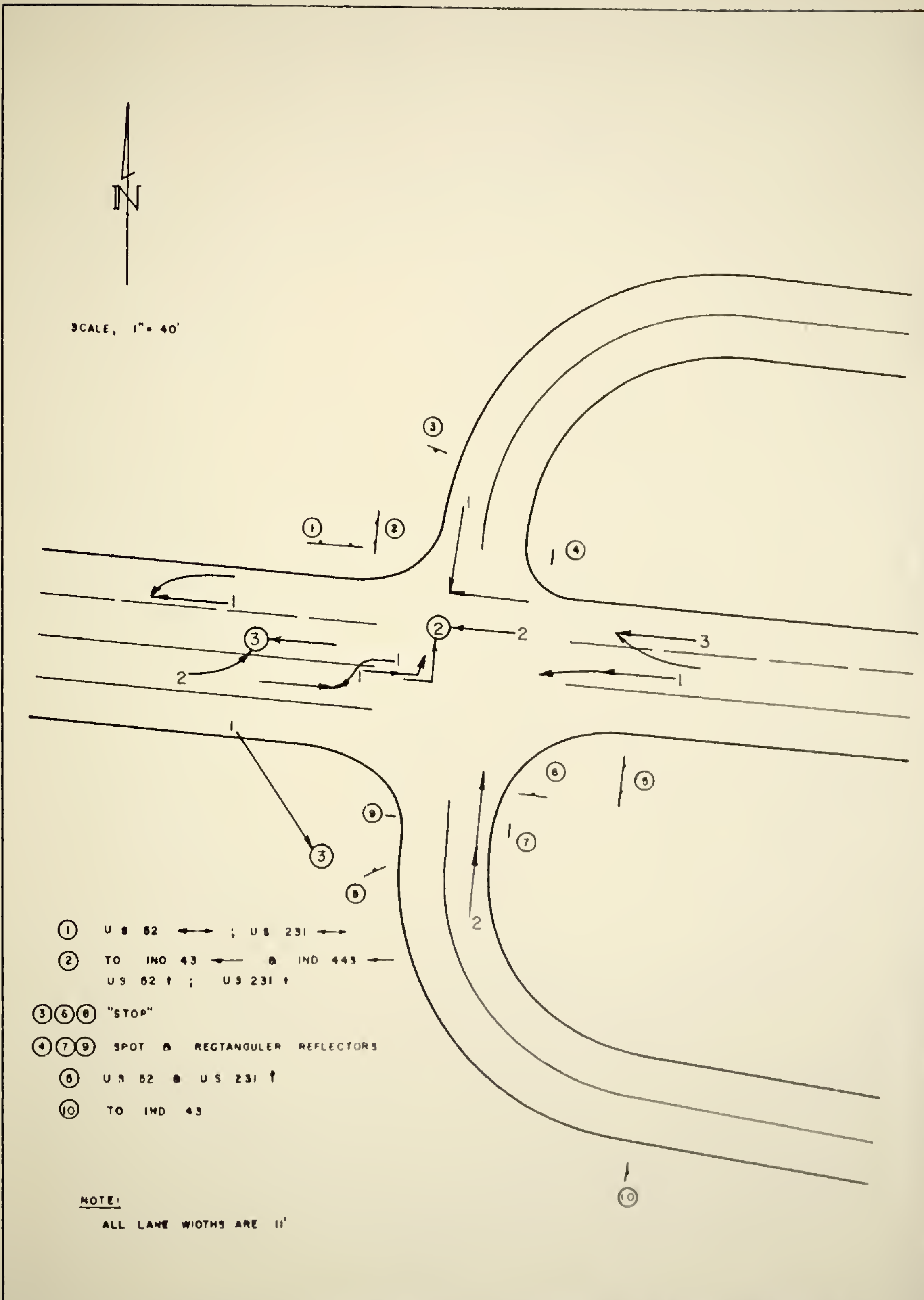


FIG. 65 – U.S. 52 BY-PASS & HAPPY HOLLOW

1963

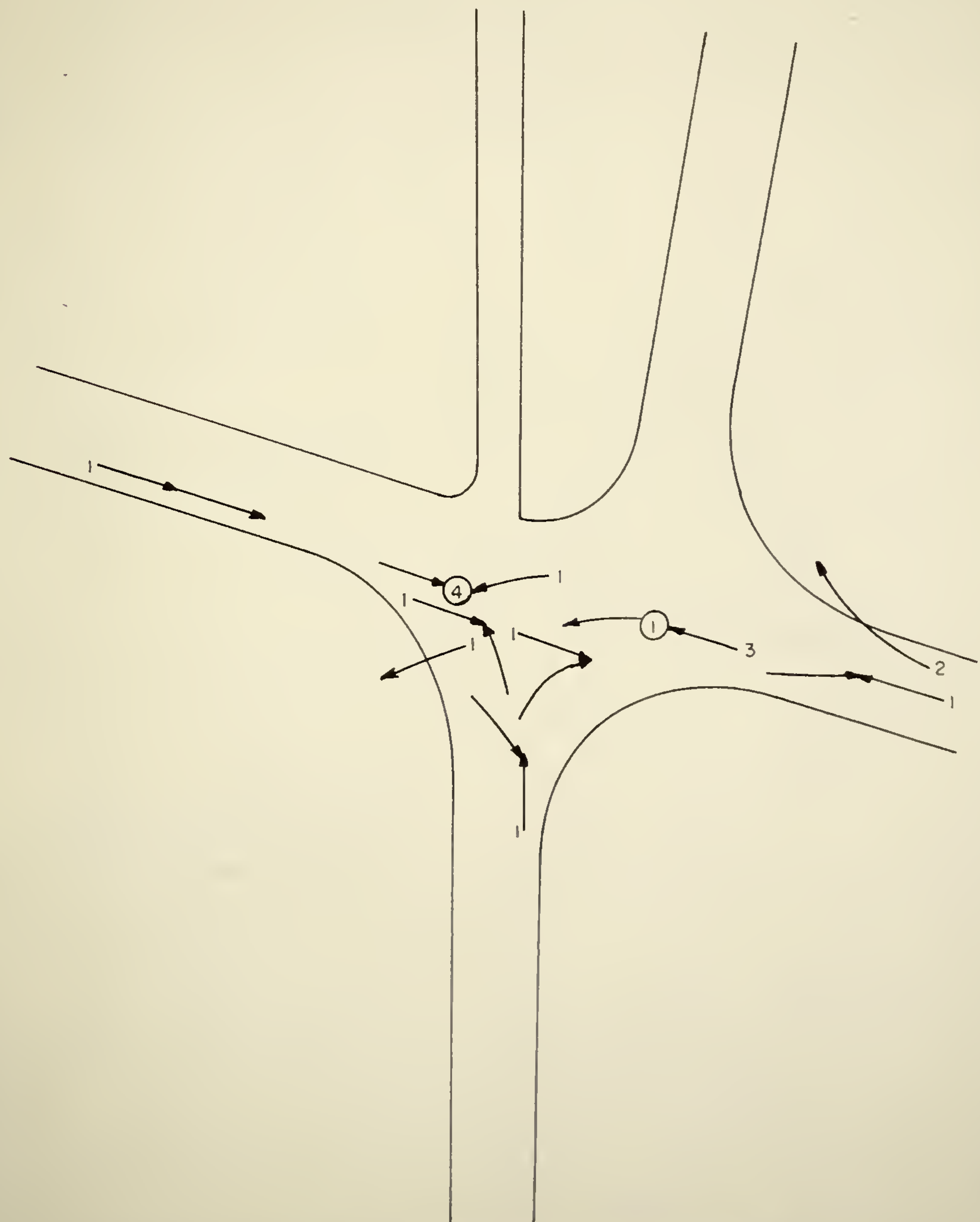


FIG. 66 – U.S. 52 BY-PASS & NINTH ST. CUTOFF

1961

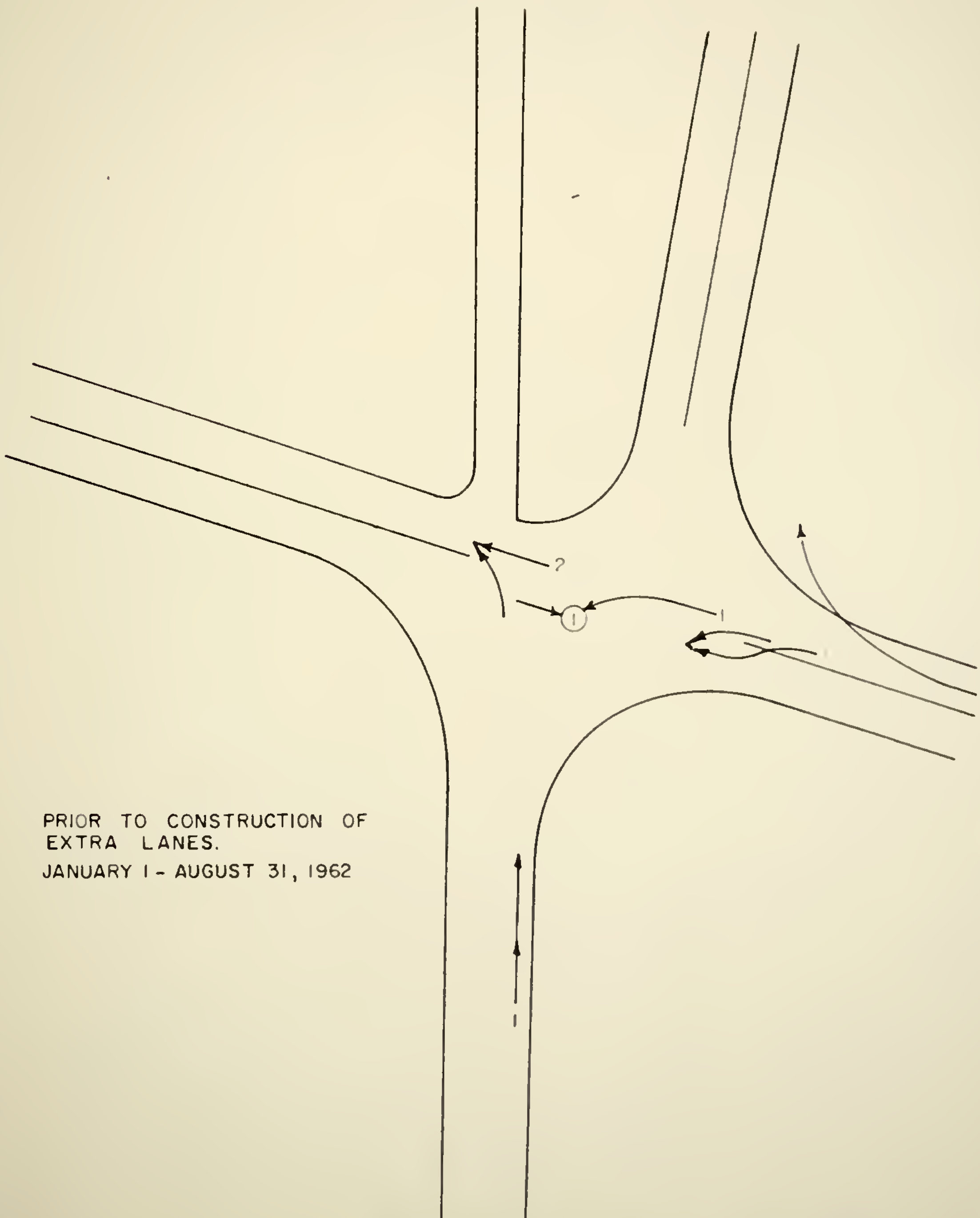


FIG. 67 – U.S. 52 BY-PASS & NINTH ST. CUTOFF

1962 A

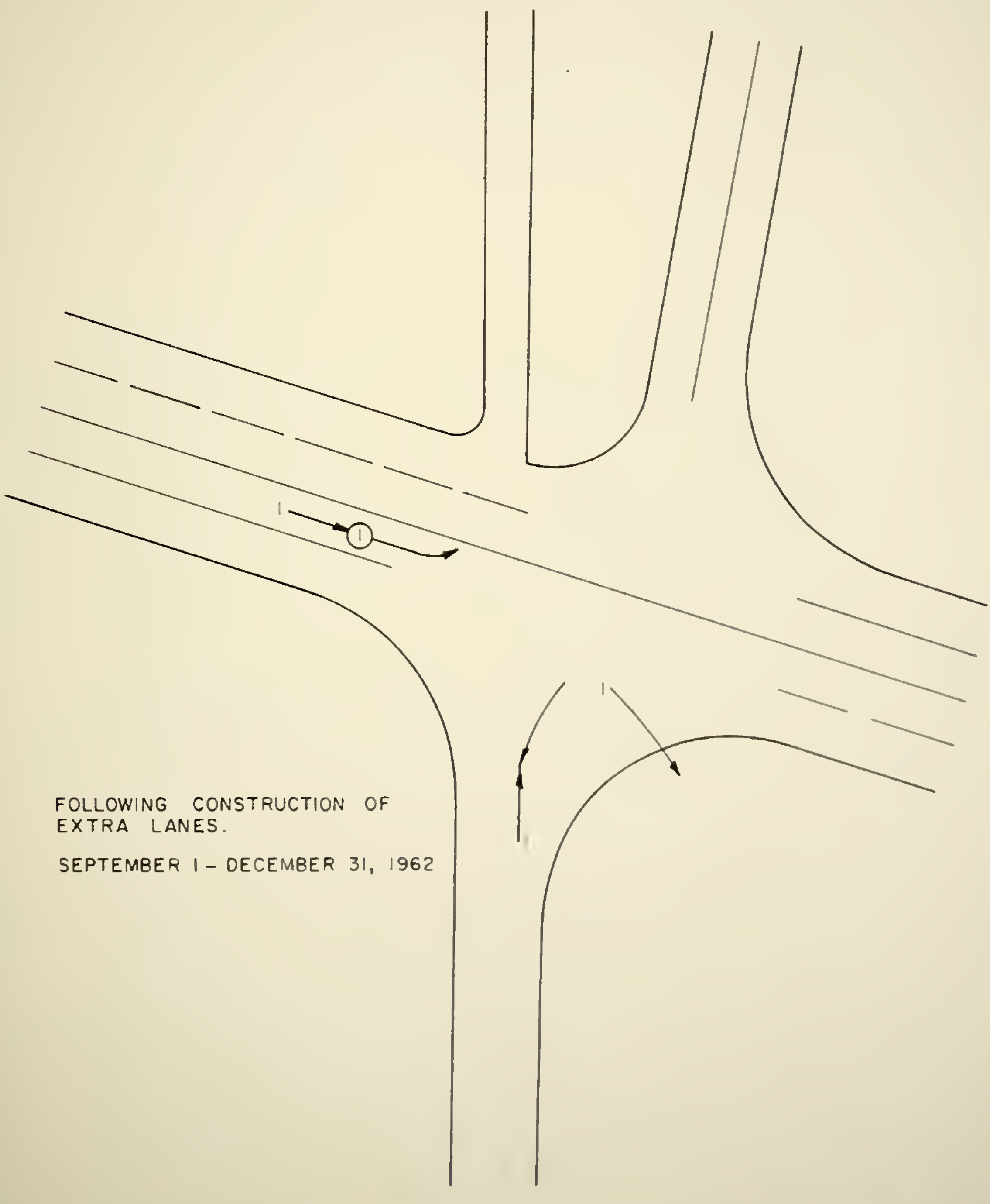


FIG. 68 – U.S. 52 BY-PASS & NINTH ST. CUTOFF

1962 B

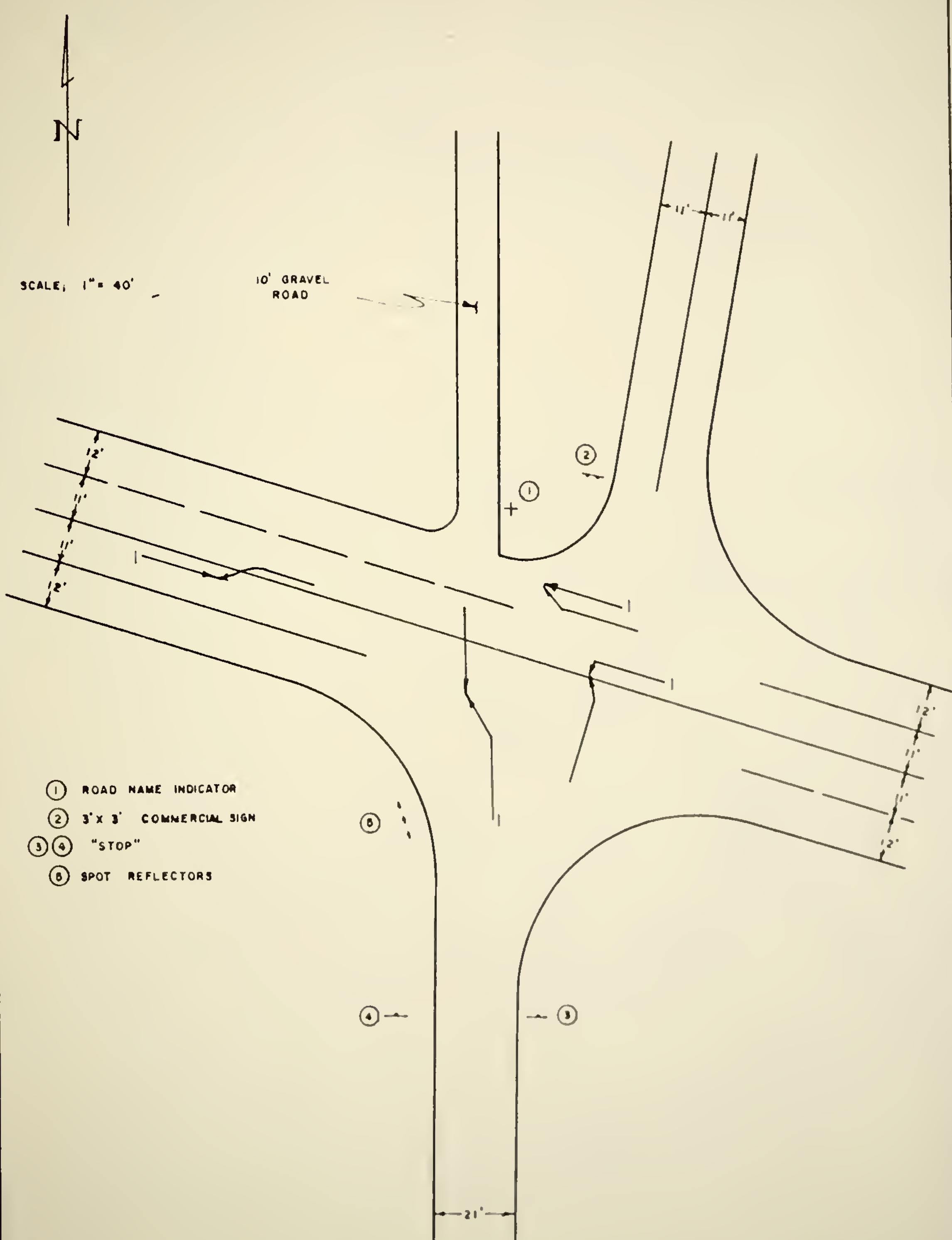


FIG. 69 – U.S. 52 BY-PASS & NINTH ST. CUTOFF

1963

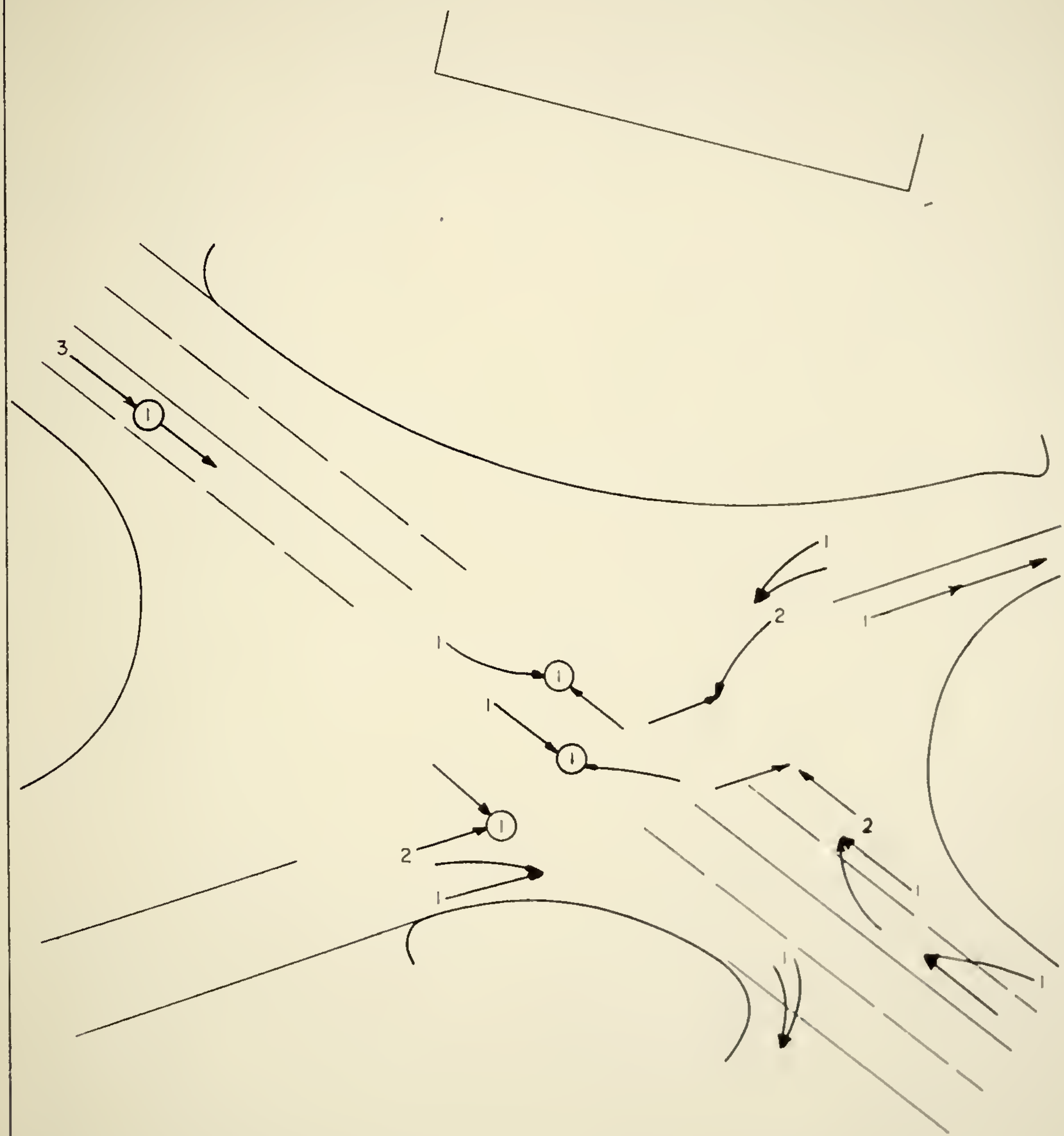


FIG. 70 - U.S. 52 BY-PASS & S.R. 25

1961

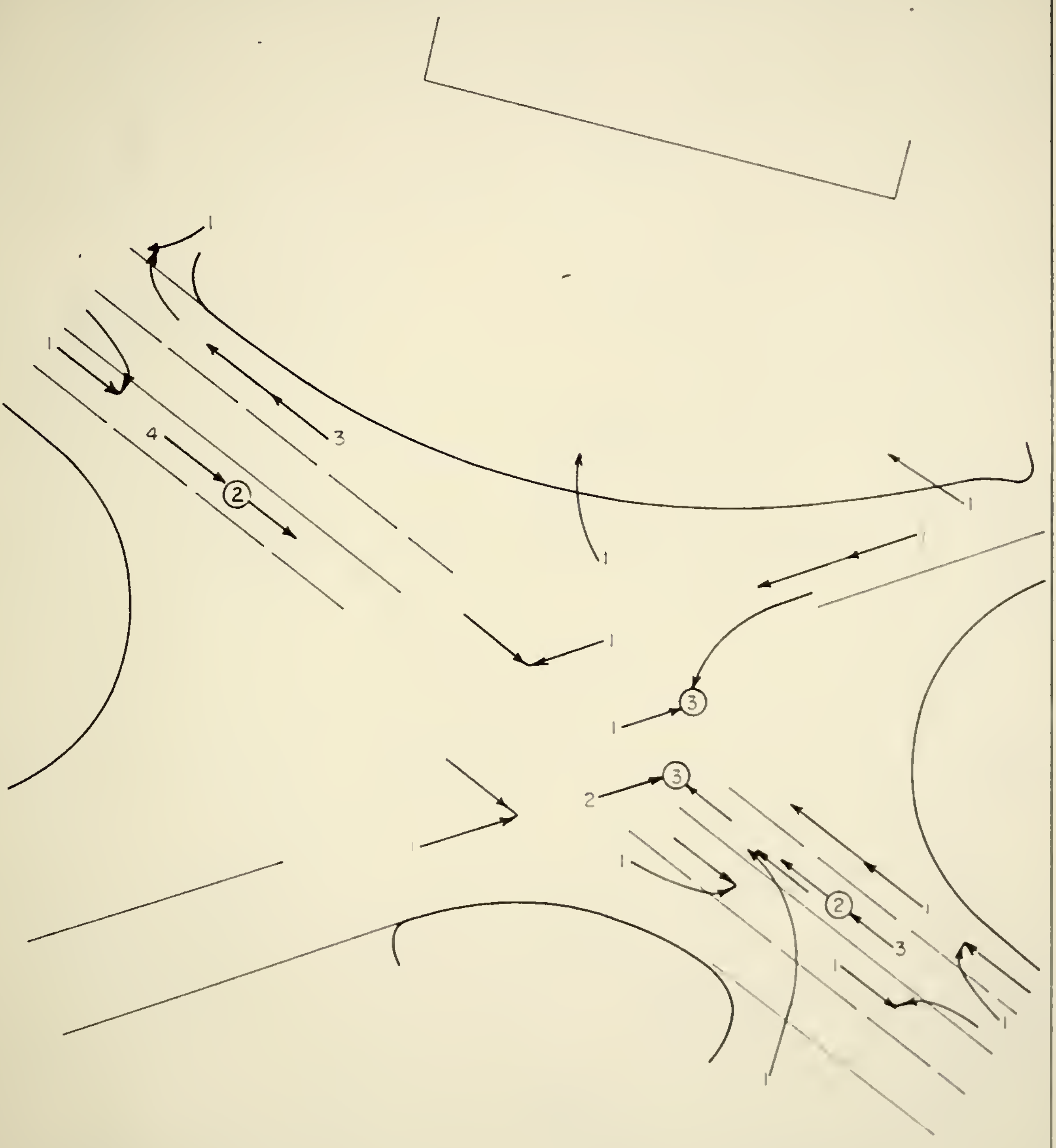


FIG. 71 - U.S. 52 BY-PASS & S.R. 25

1962

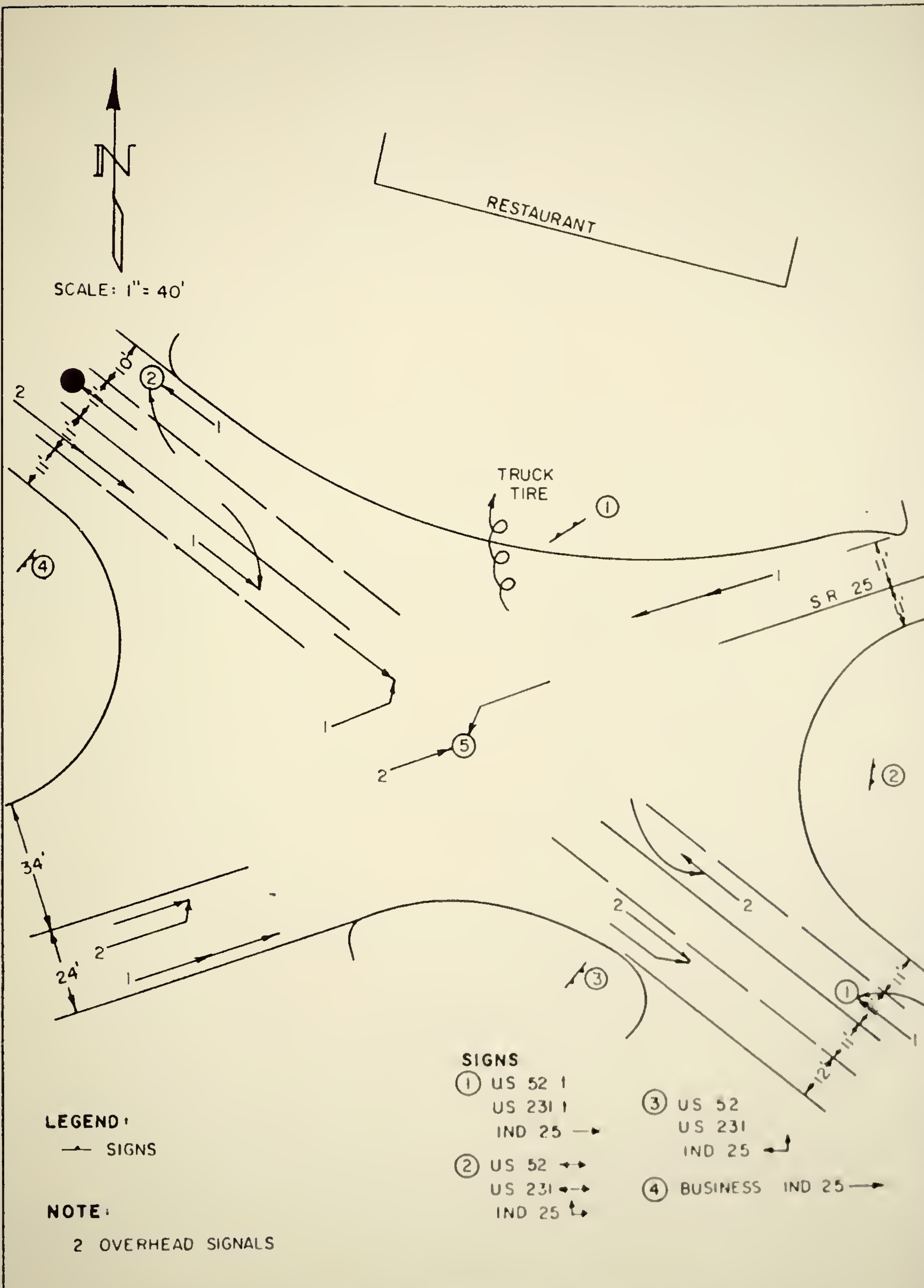


FIG. 72 - U.S. 52 BY-PASS & S.R. 25

1963

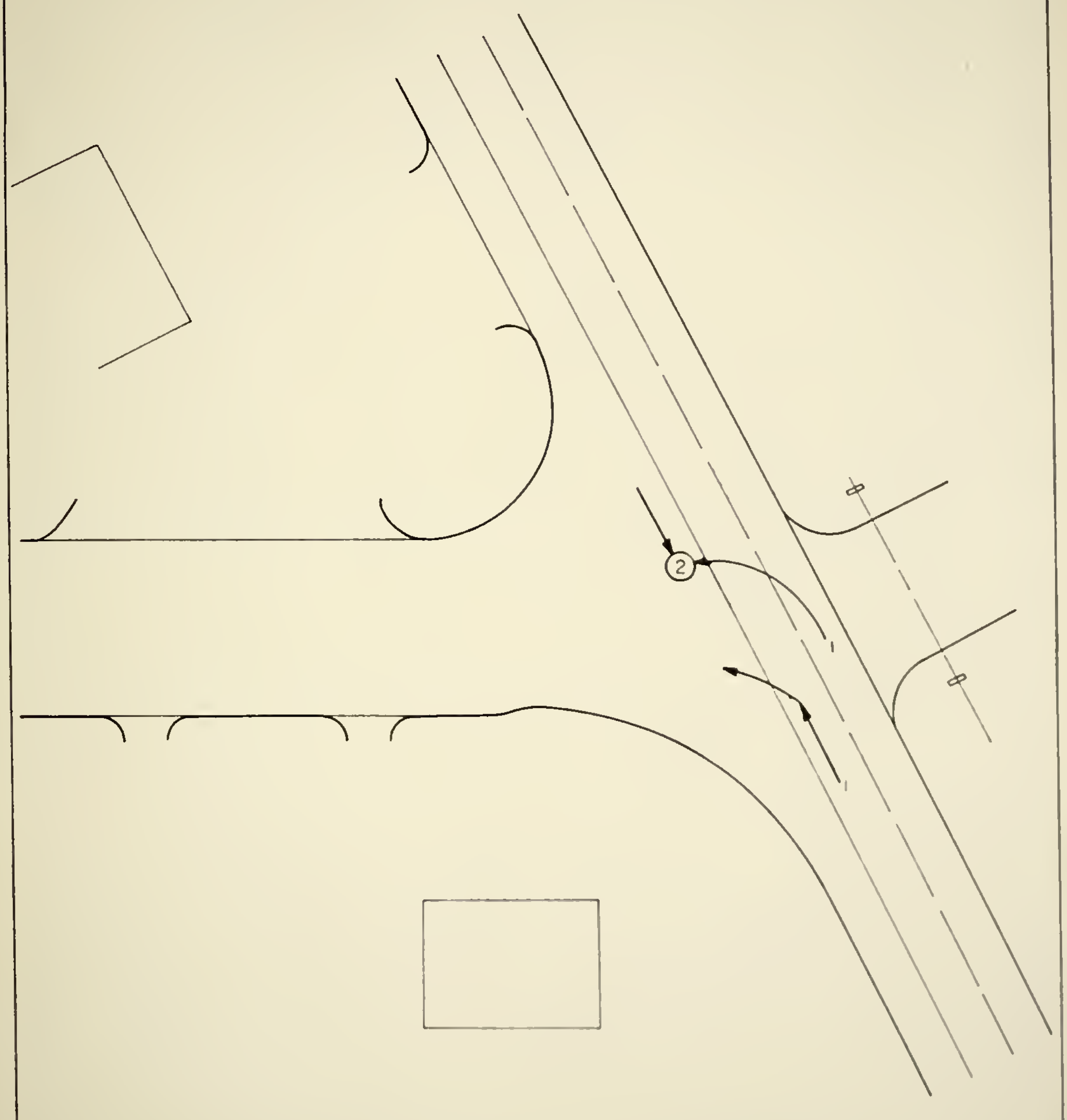


FIG. 73 - U.S. 52 BY-PASS & UNDERWOOD ST.

1961

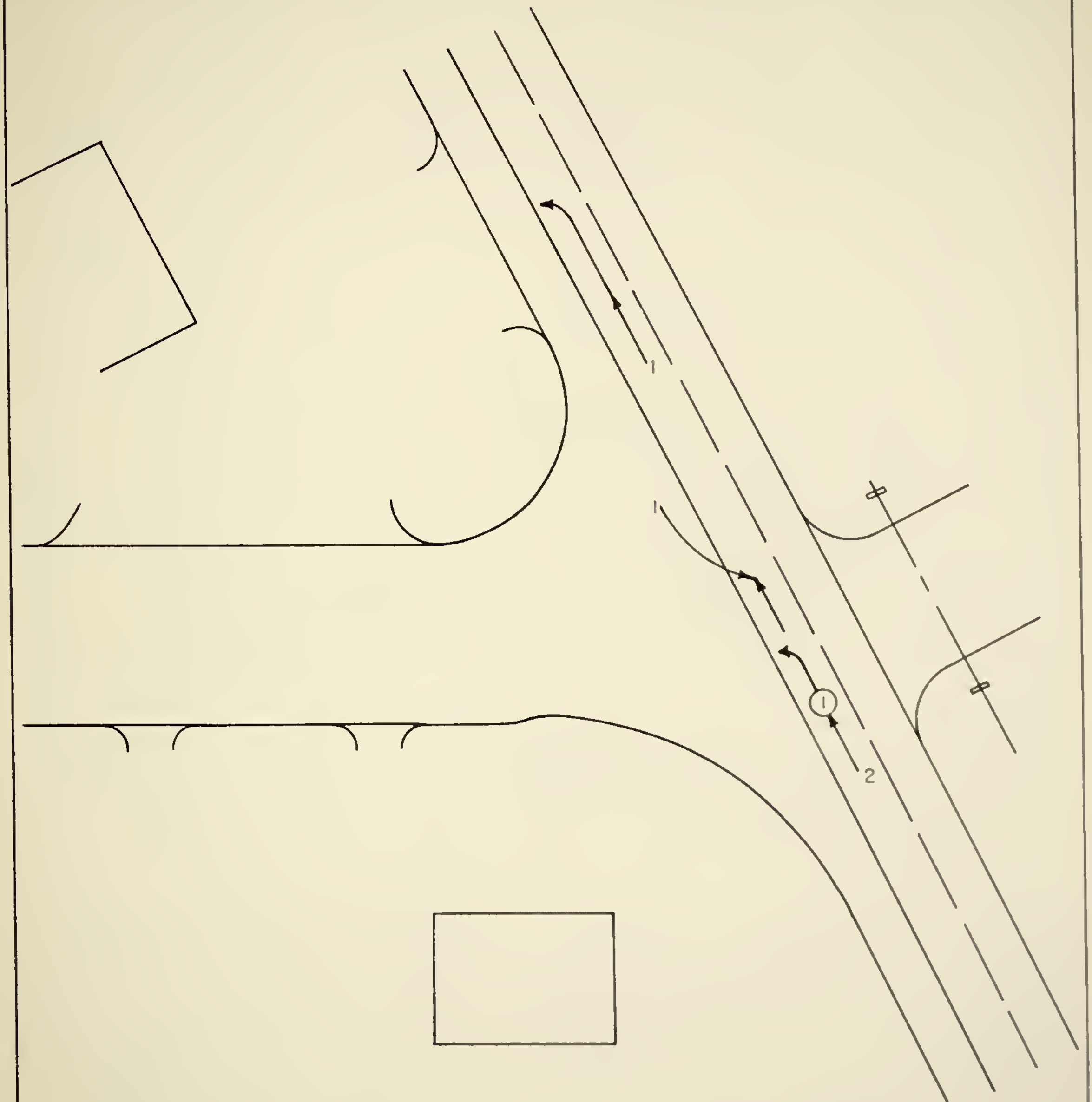


FIG. 74 - U.S. 52 BY-PASS & UNDERWOOD ST.

1962

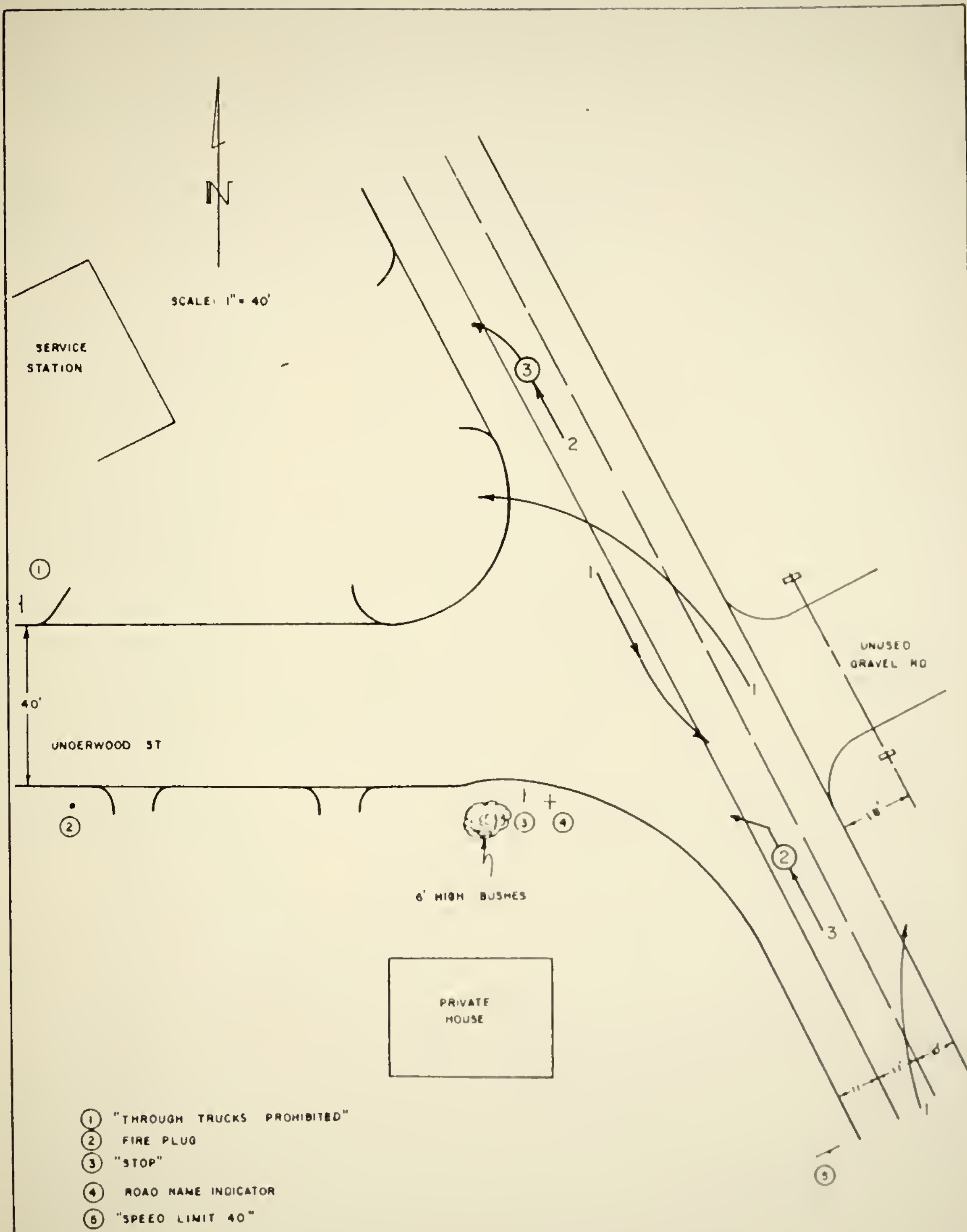


FIG. 75 - U. S. 52 BY-PASS & UNDERWOOD ST.

1963

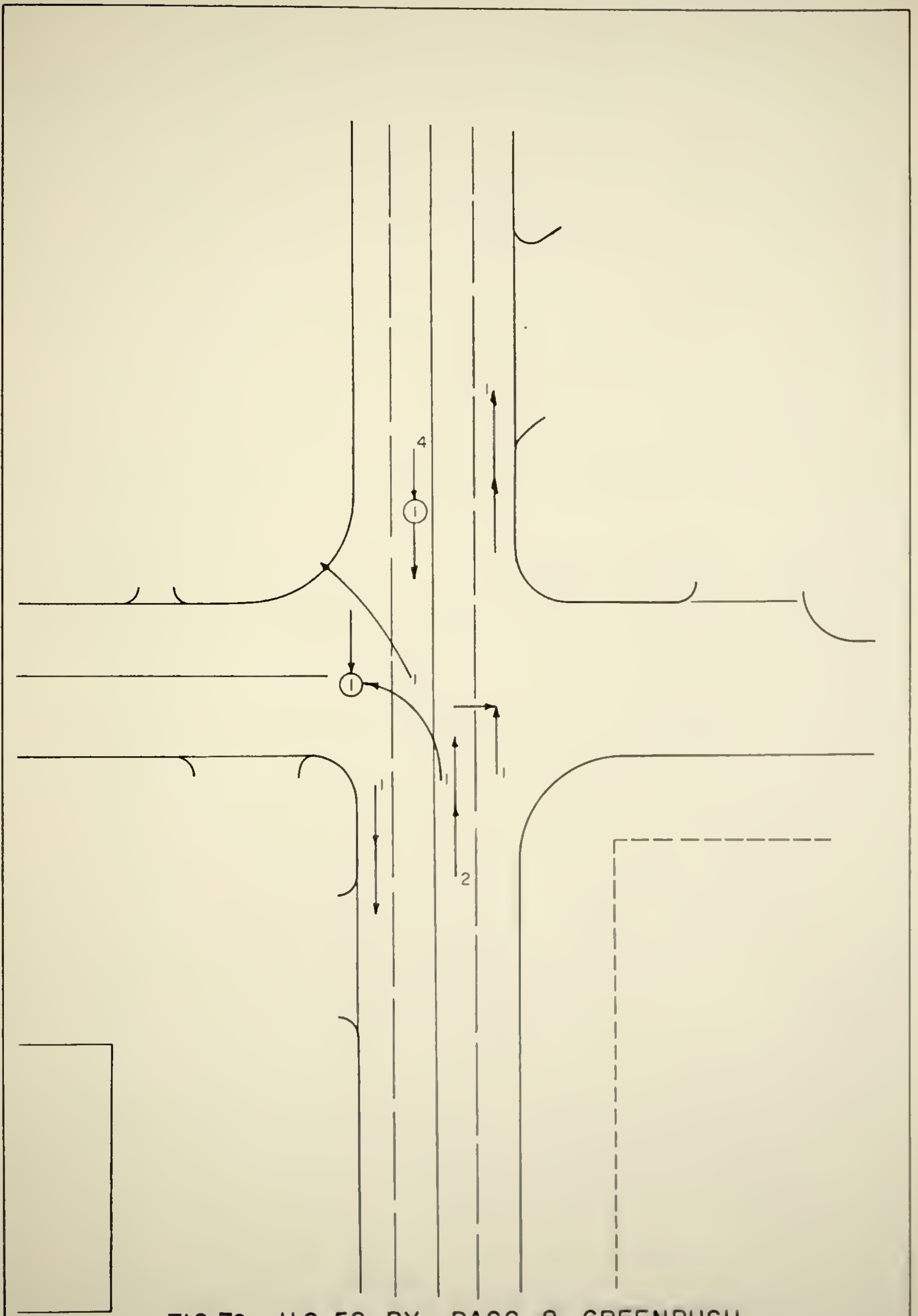


FIG. 76 - U.S. 52 BY - PASS & GREENBUSH

1961

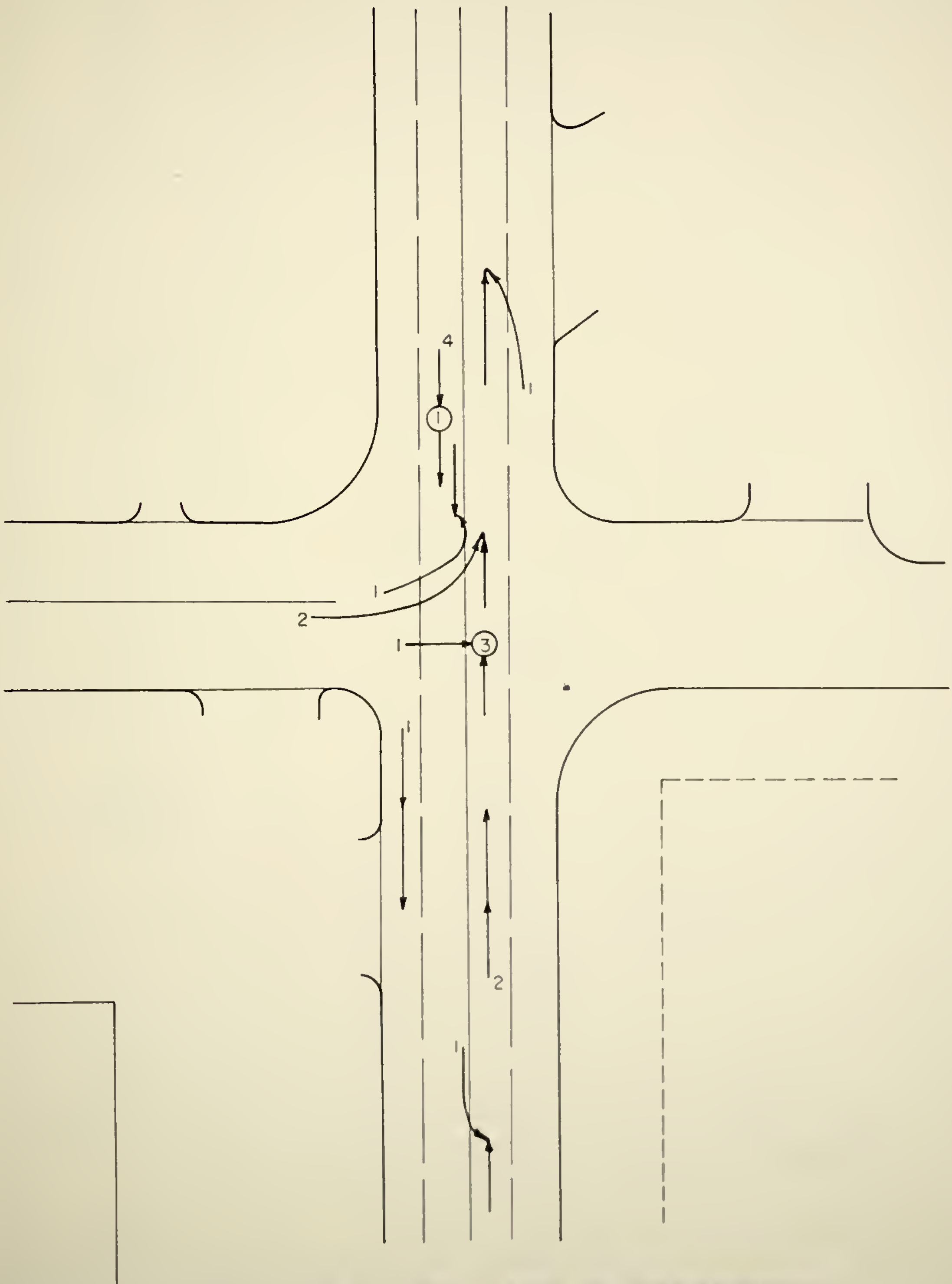


FIG.77 - U.S. 52 BY - PASS & GREENBUSH

1962

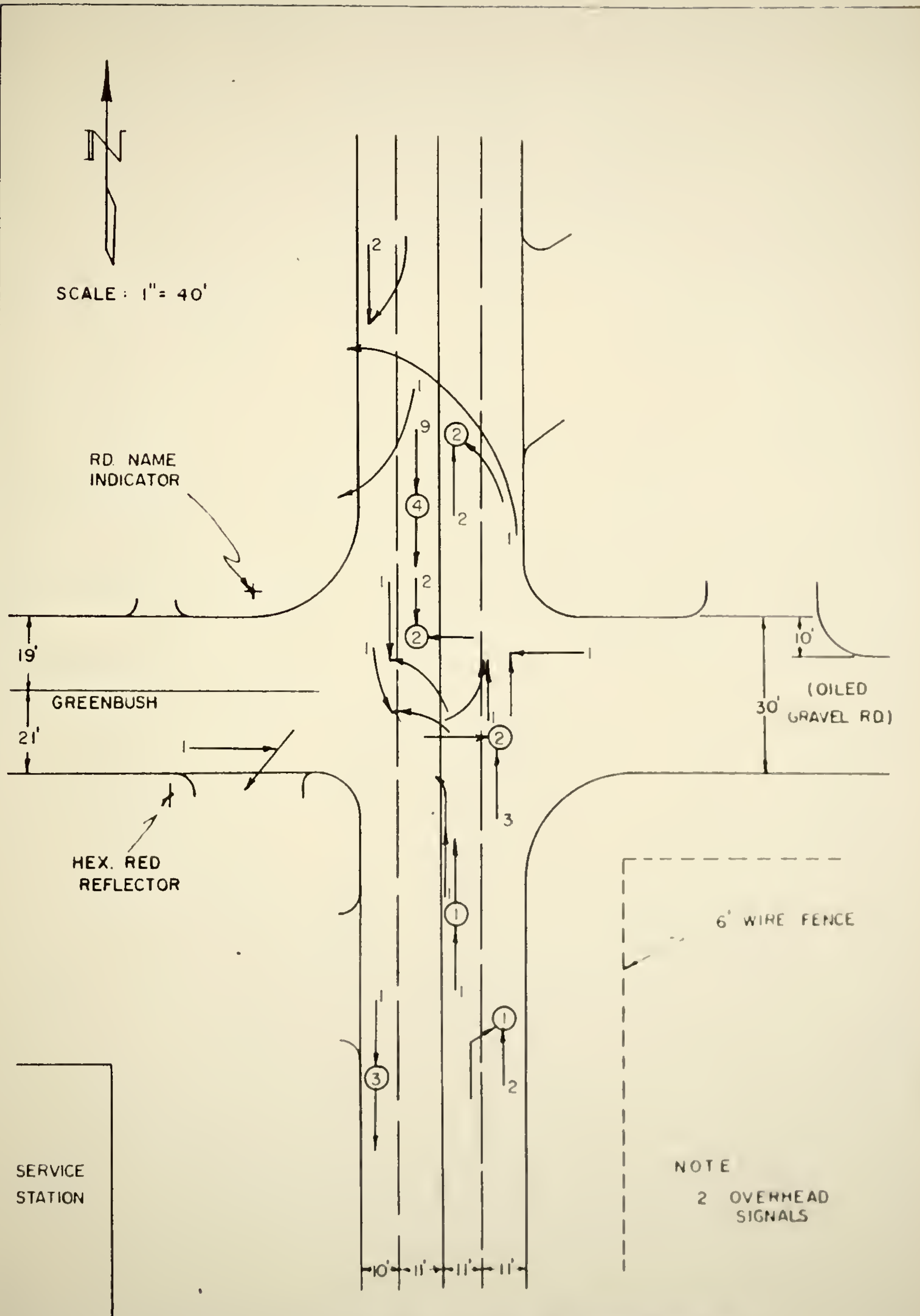


FIG. 78 – U.S. 52 BY-PASS & GREENBUSH

1963

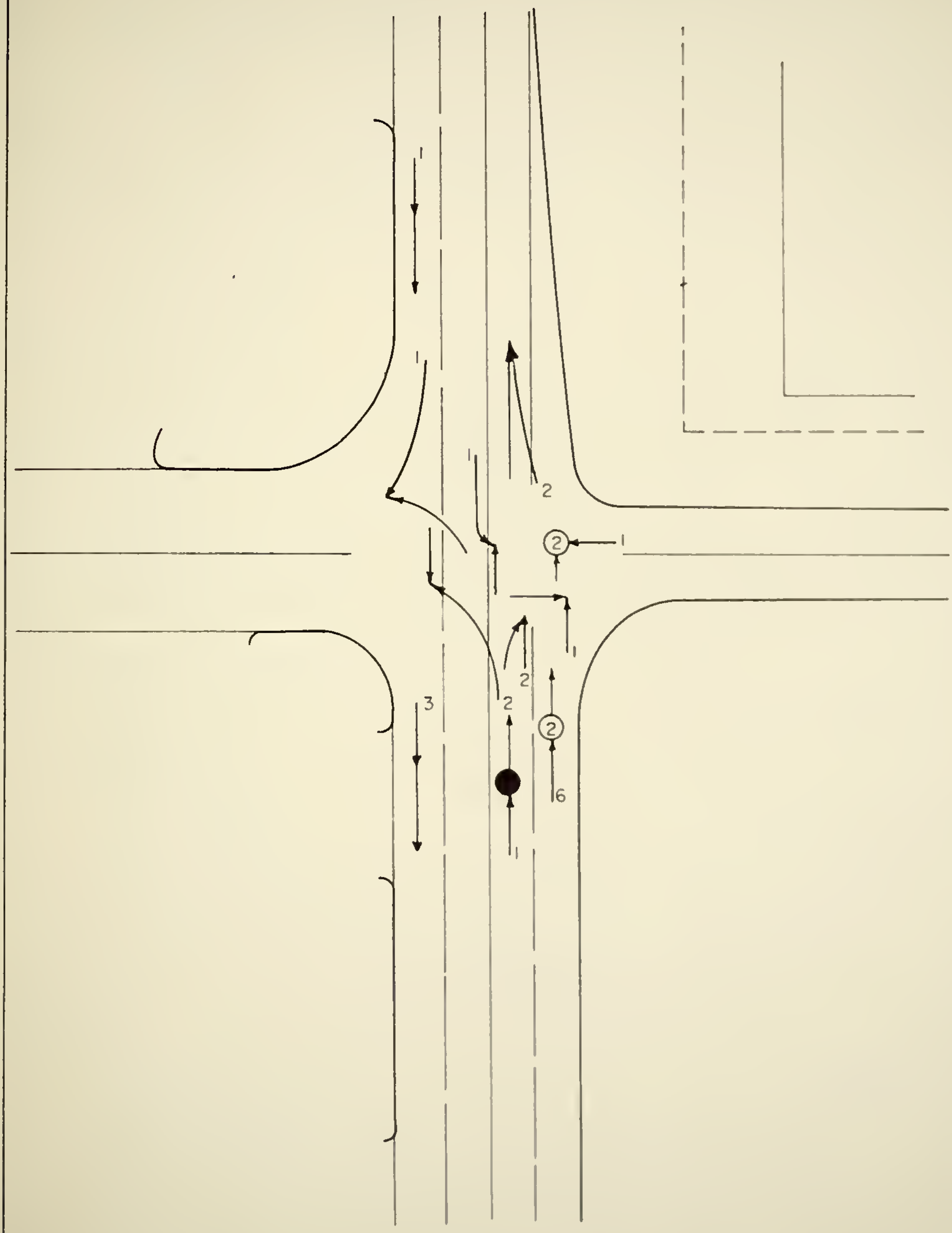


FIG.79 – U.S. 52 BY-PASS & UNION

1961

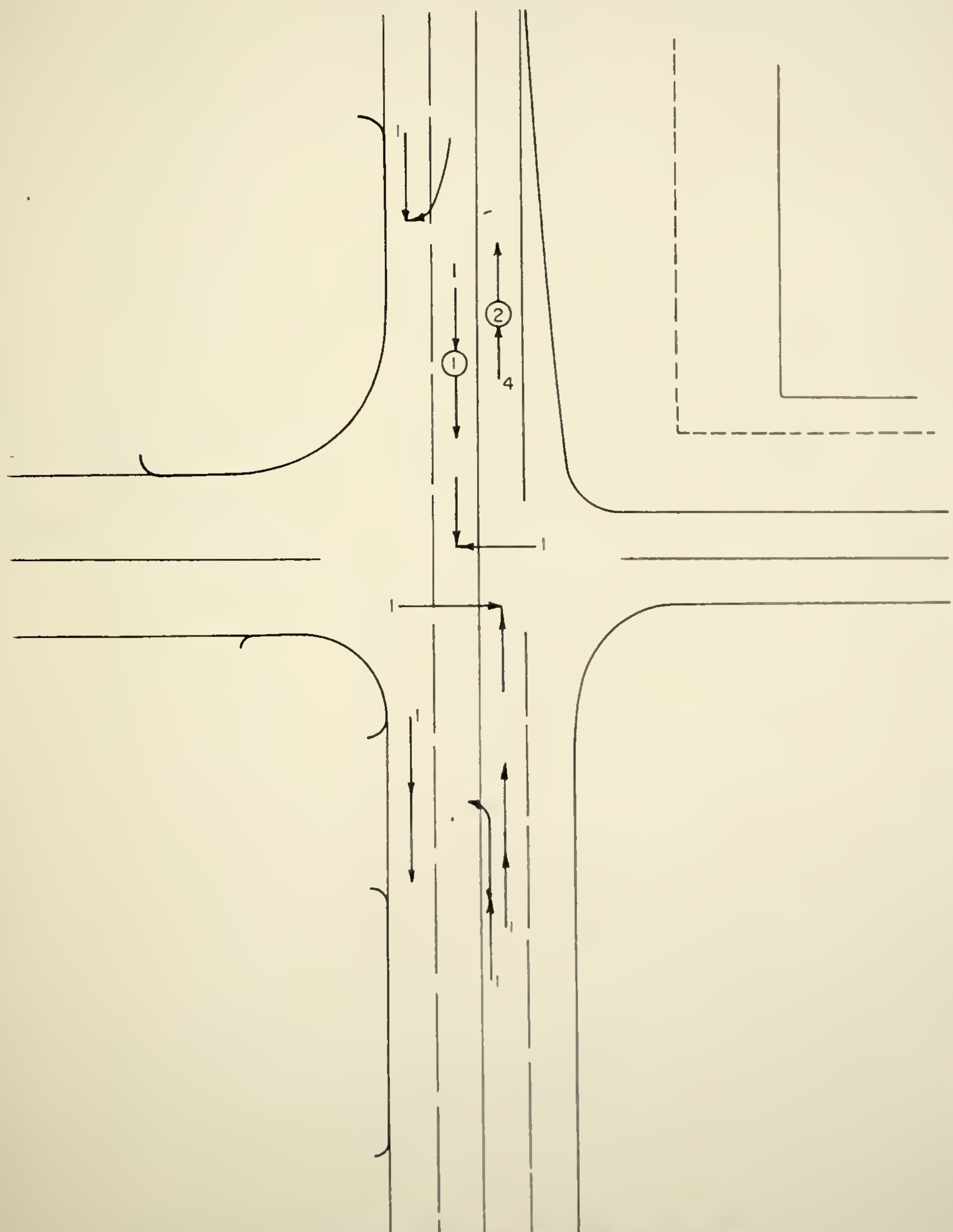


FIG. 80 – U.S. 52 BY-PASS & UNION

1962

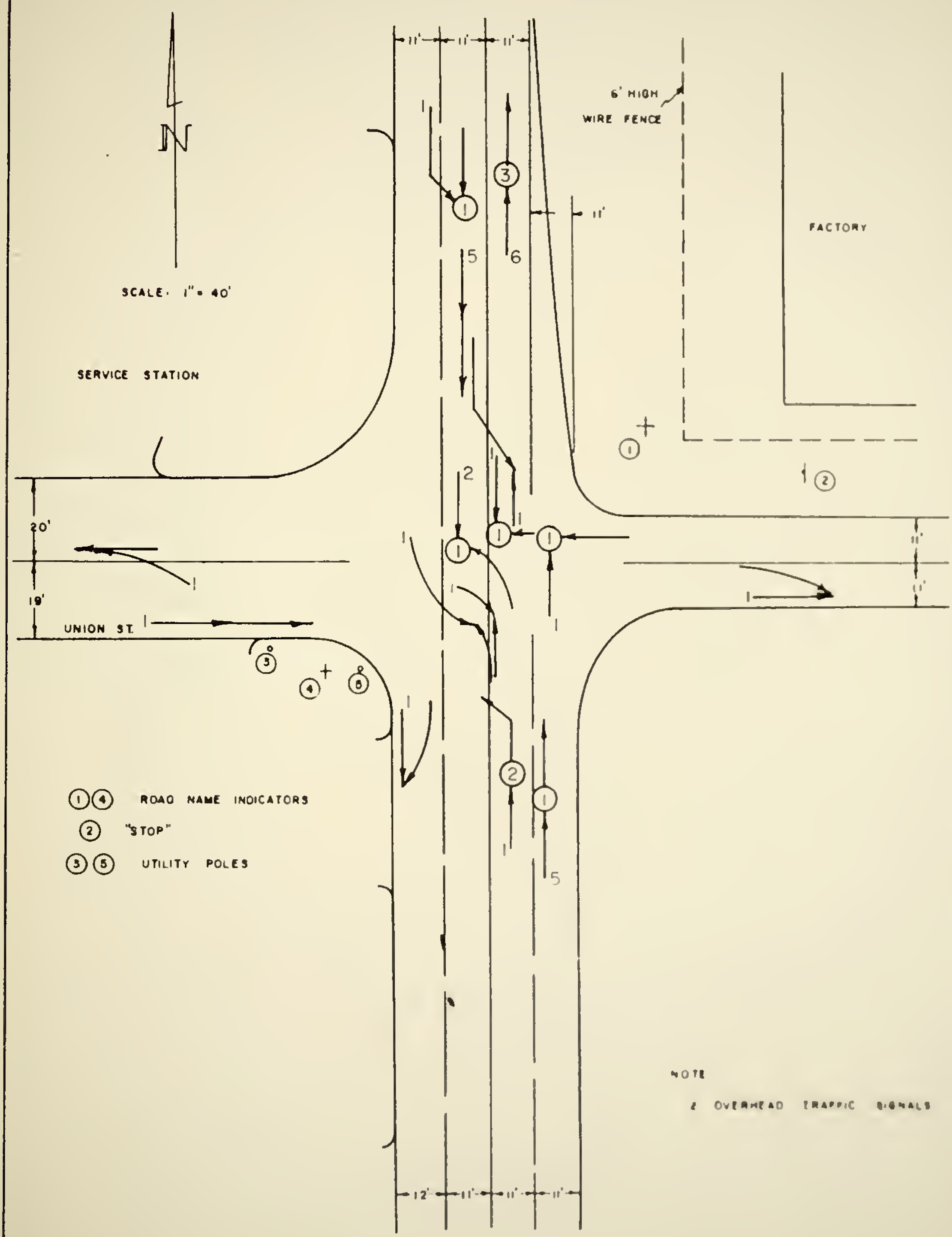


FIG. 81 - U.S. 52 BY-PASS & UNION

1963

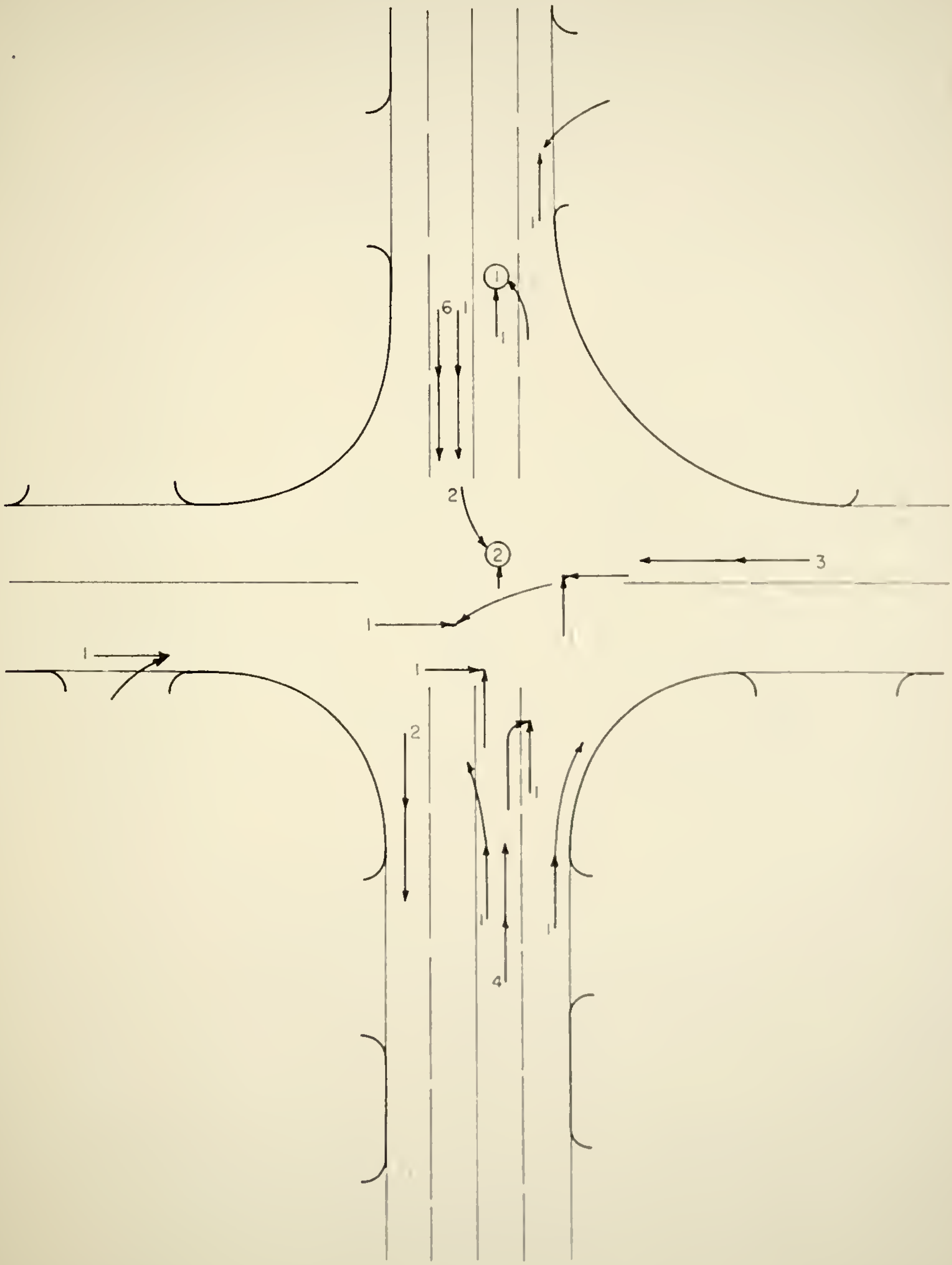


FIG. 82 - U.S 52 BY-PASS & S.R. 26

1961

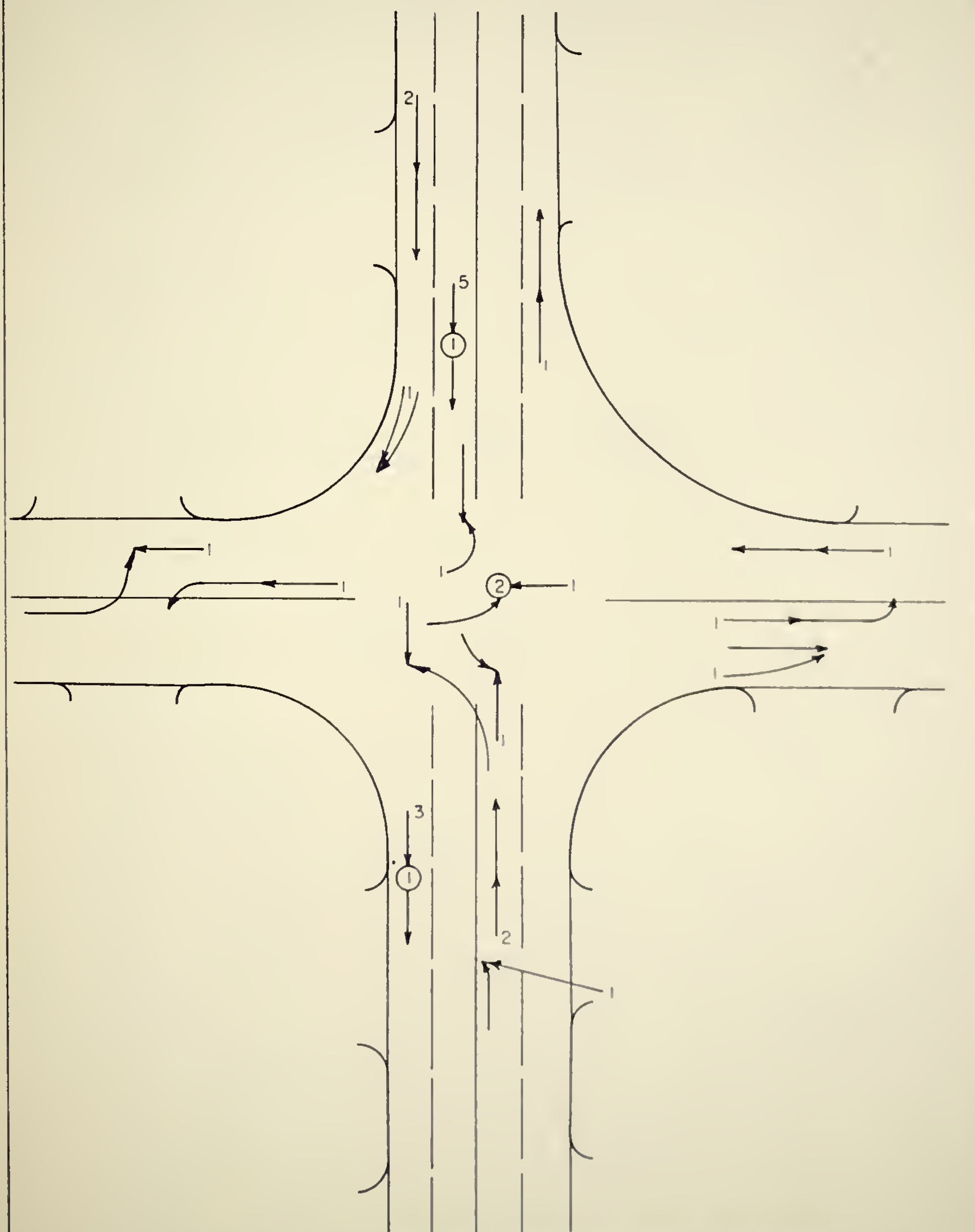


FIG. 83 - U.S. 52 BY-PASS & S.R. 26

1962

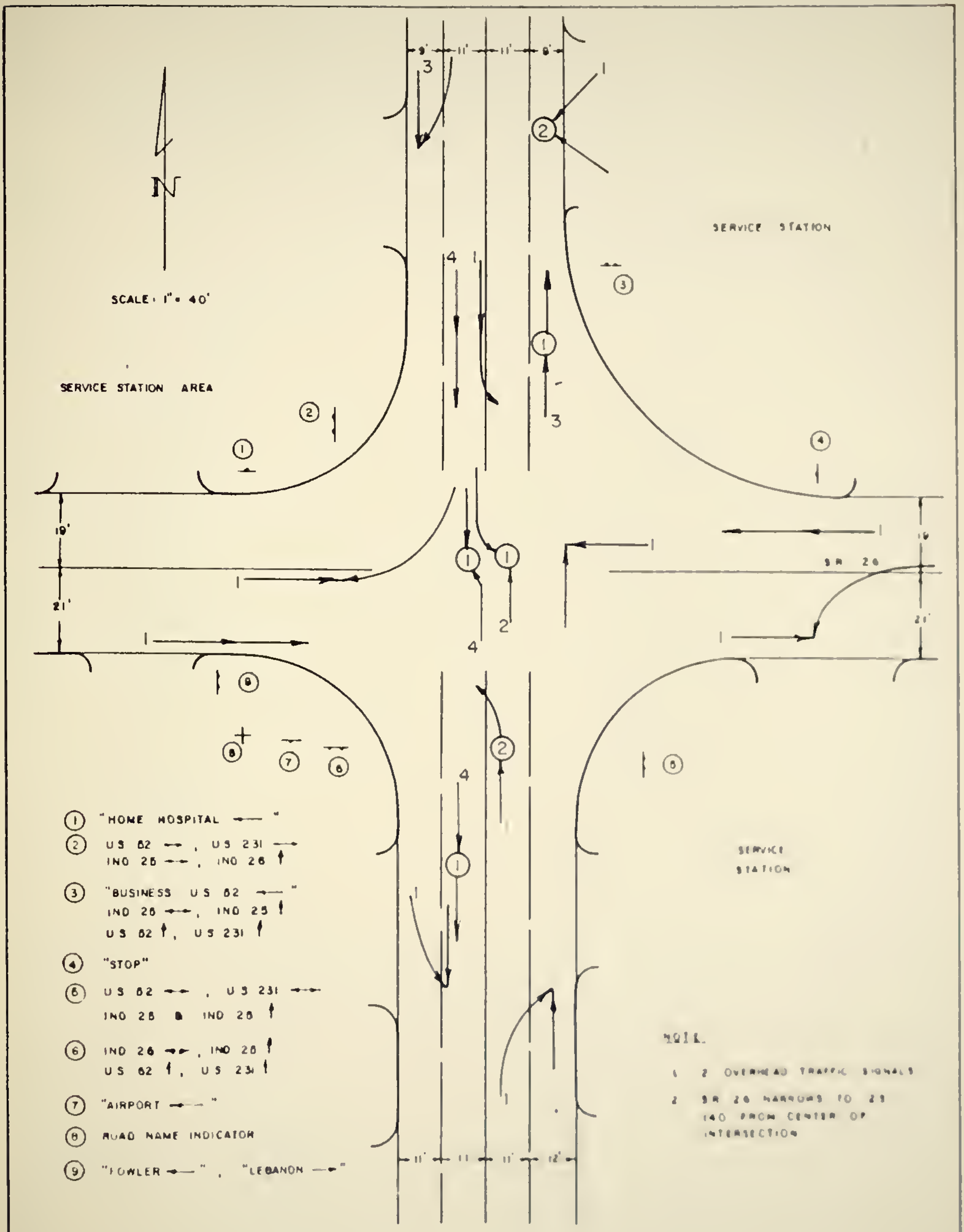


FIG. 84 - U.S. 52 BY-PASS & S.R 26

1963

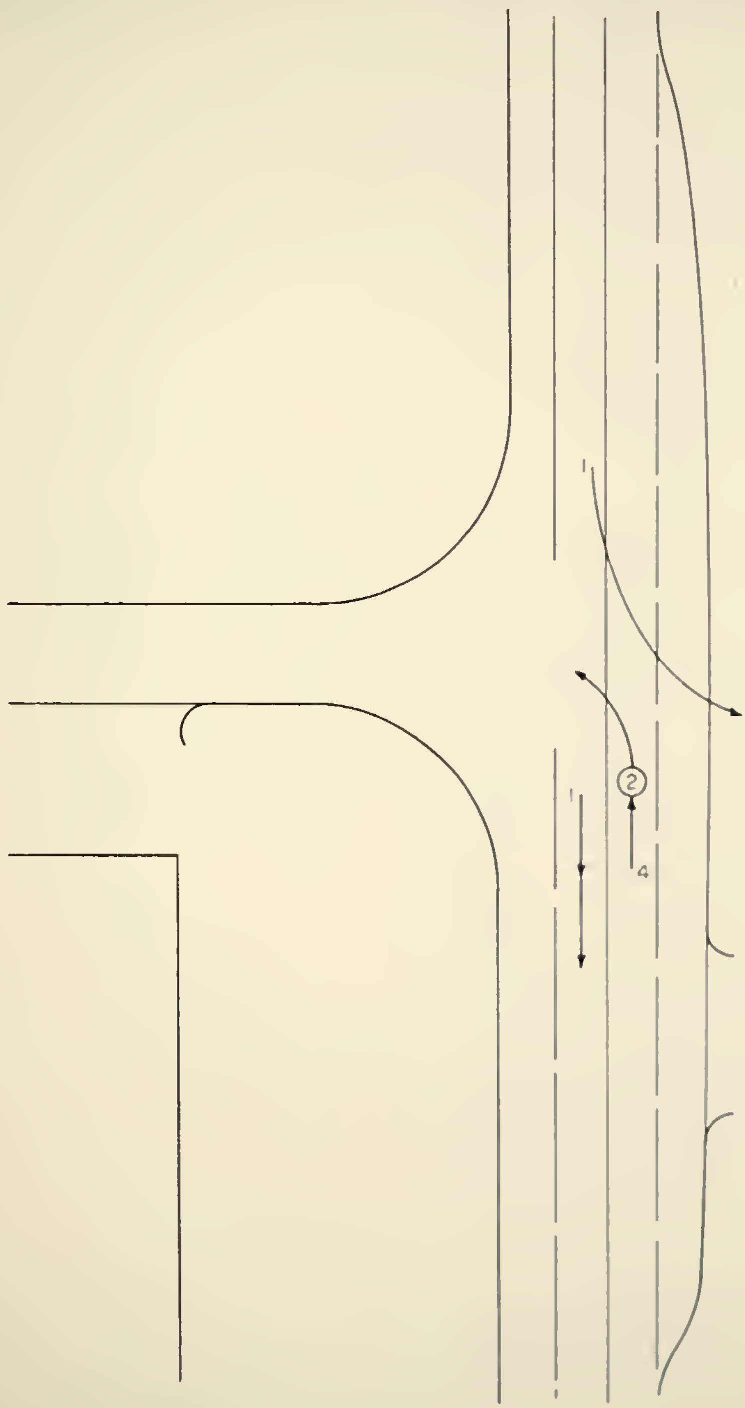


FIG. 85 – U. S. 52 BY-PASS & KOSSUTH ST.

1961

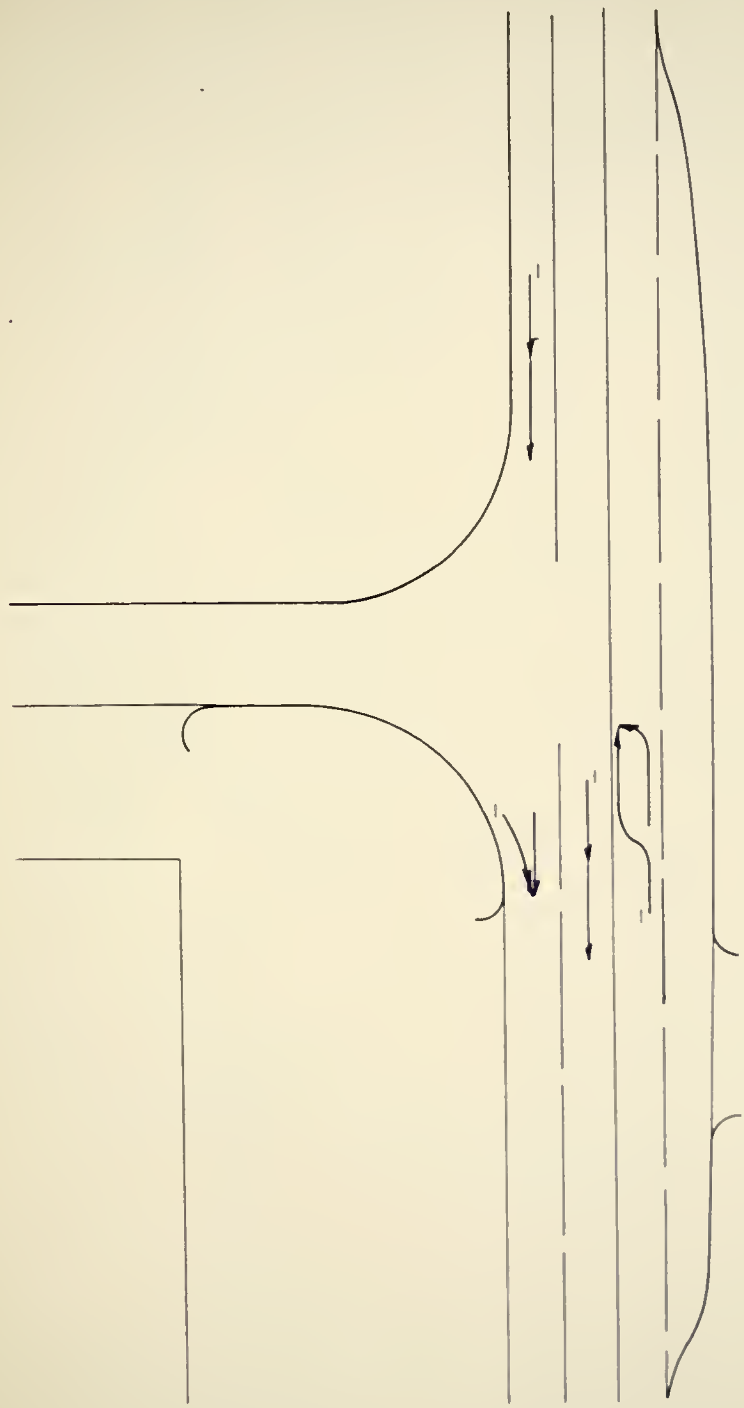


FIG. 86 – U.S. 52 BY-PASS & KOSSUTH ST.

1962

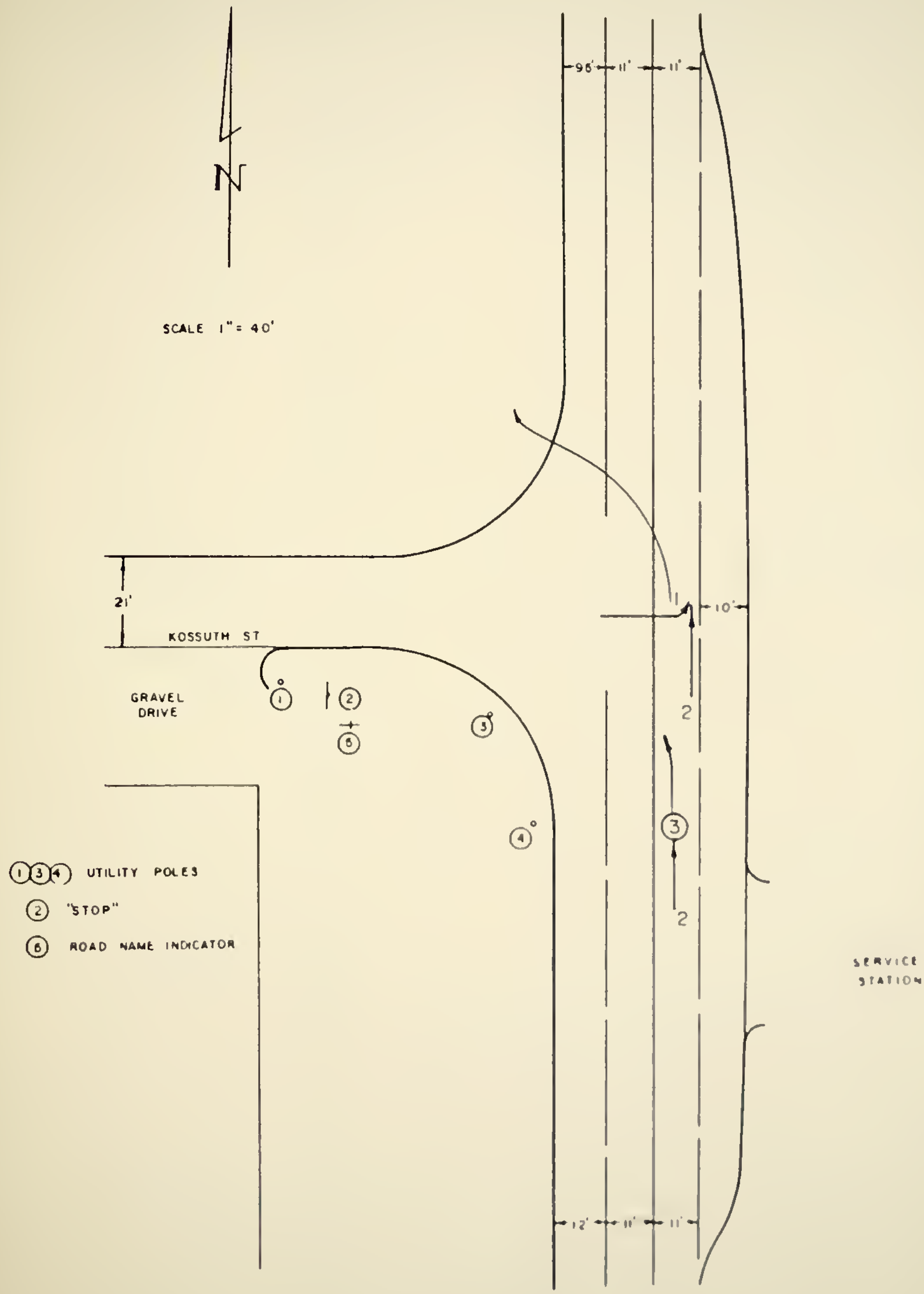


FIG. 87 – U.S. 52 BY-PASS & KOSSUTH ST.

1963

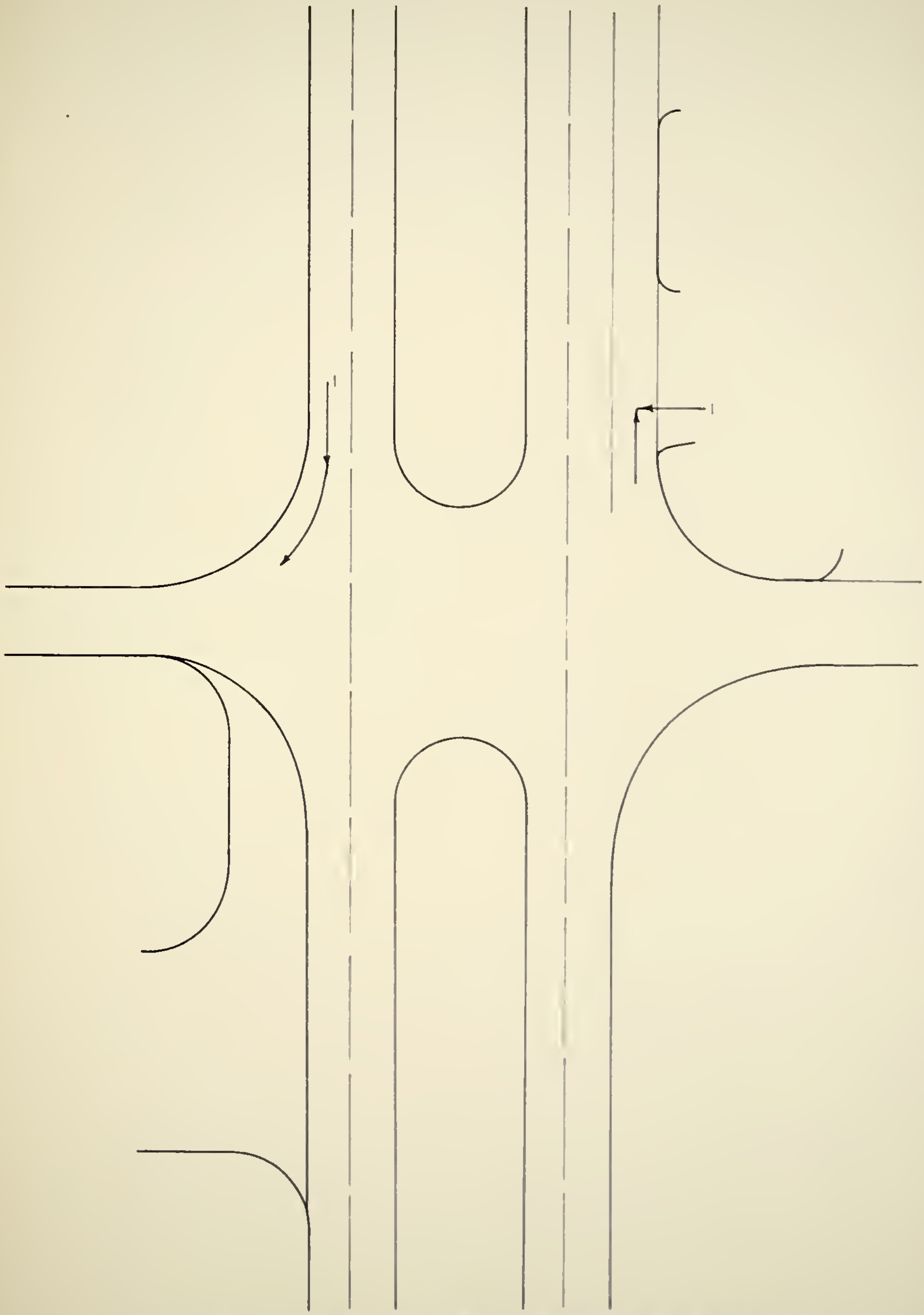


FIG. 88 – U.S. 52 BY – PASS & McCARTY

1961

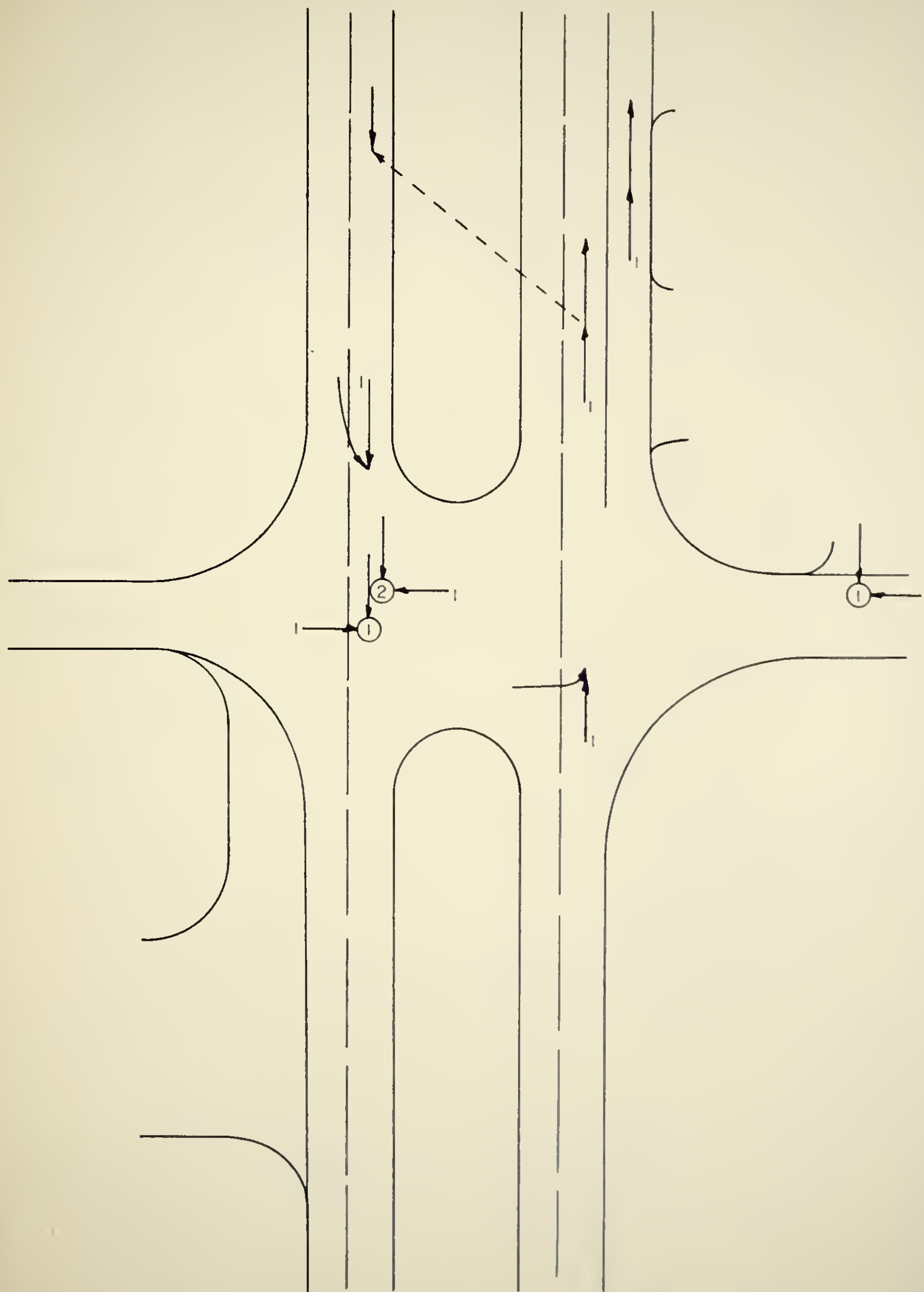


FIG. 89 – U.S. 52 BY – PASS & McCARTY

1962

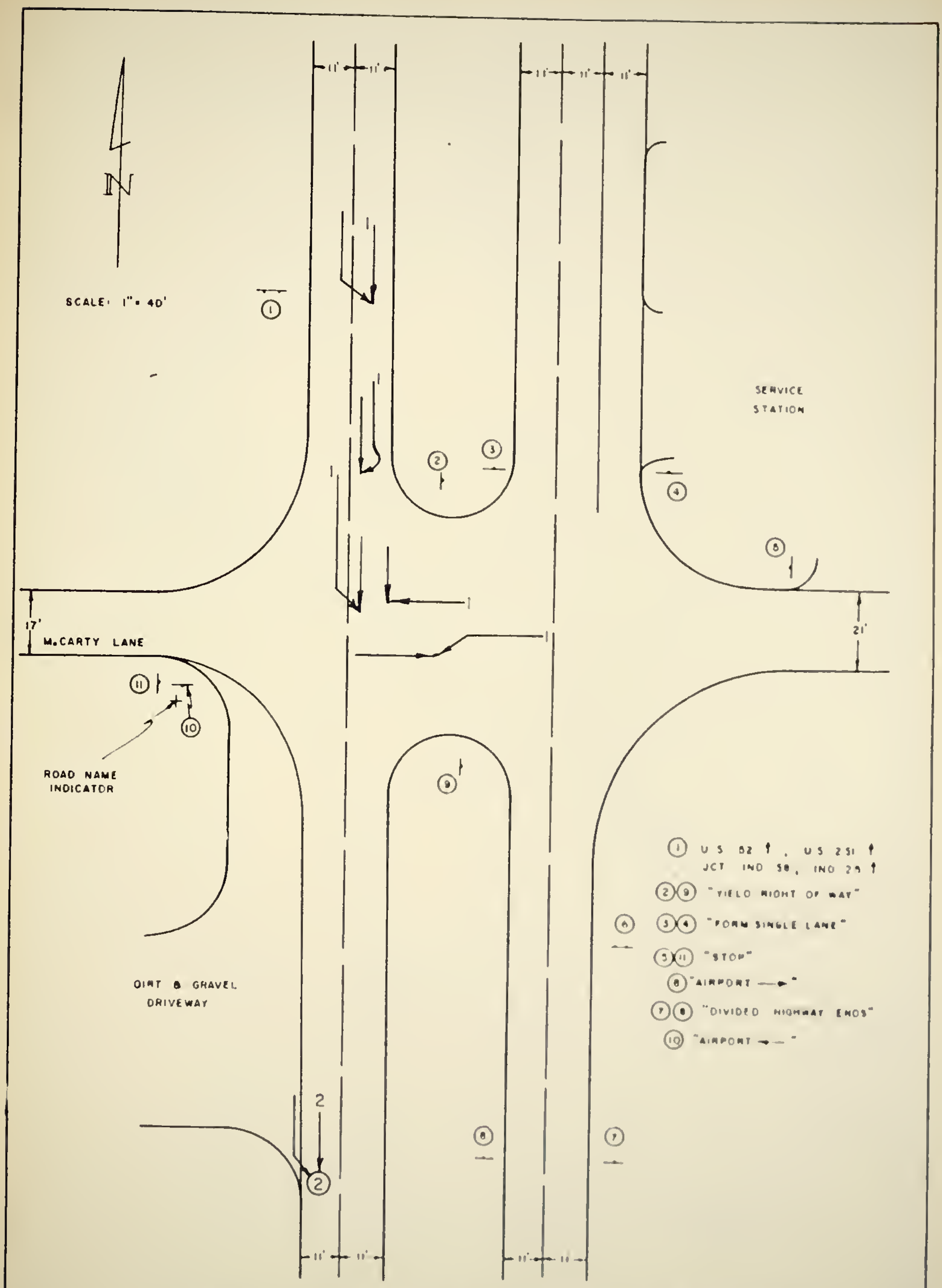


FIG. 90 - US 52 BY-PASS & McCARTY

1963

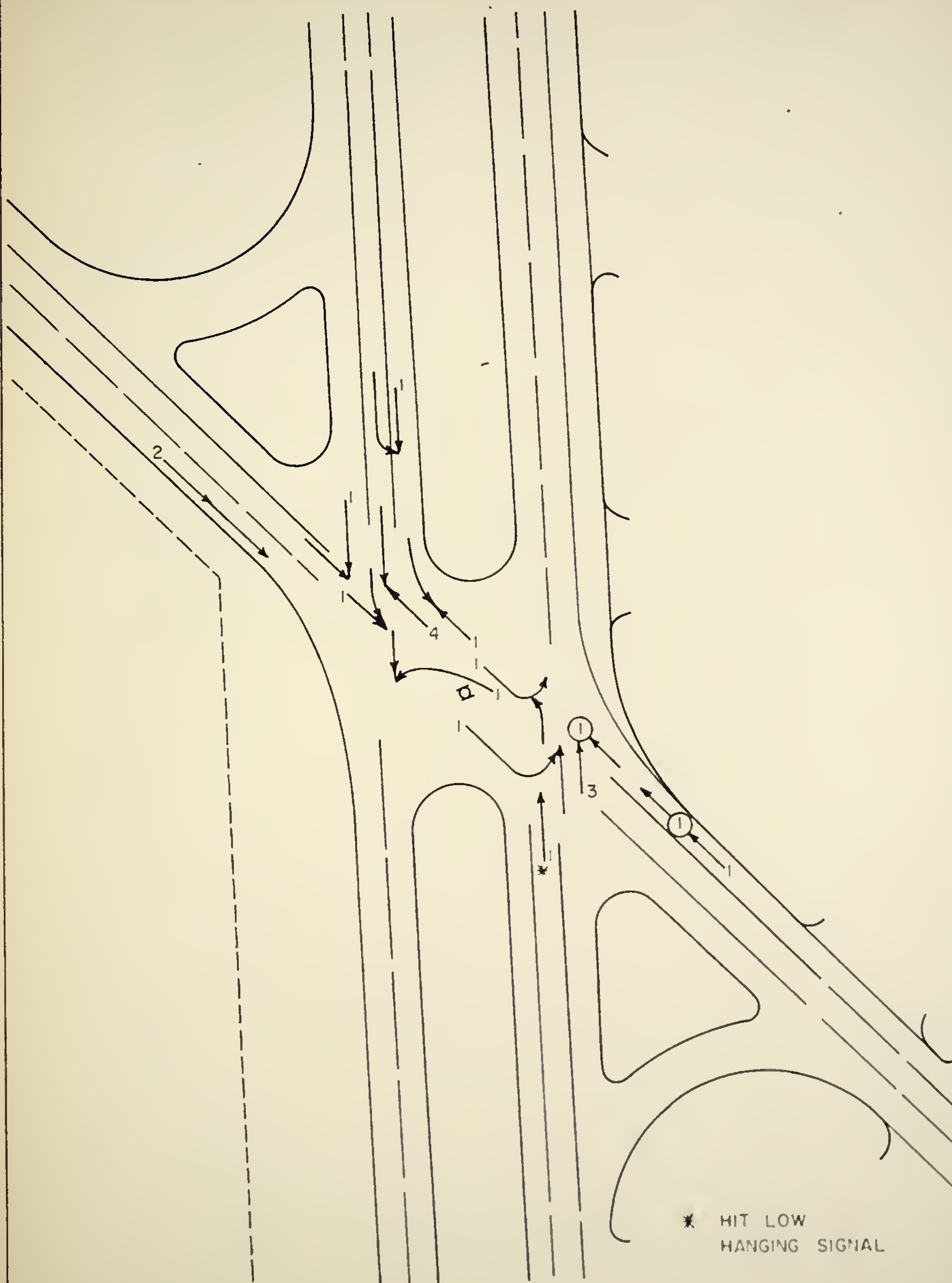


FIG.91 – U.S. 52 BY-PASS & S.R. 38

1961

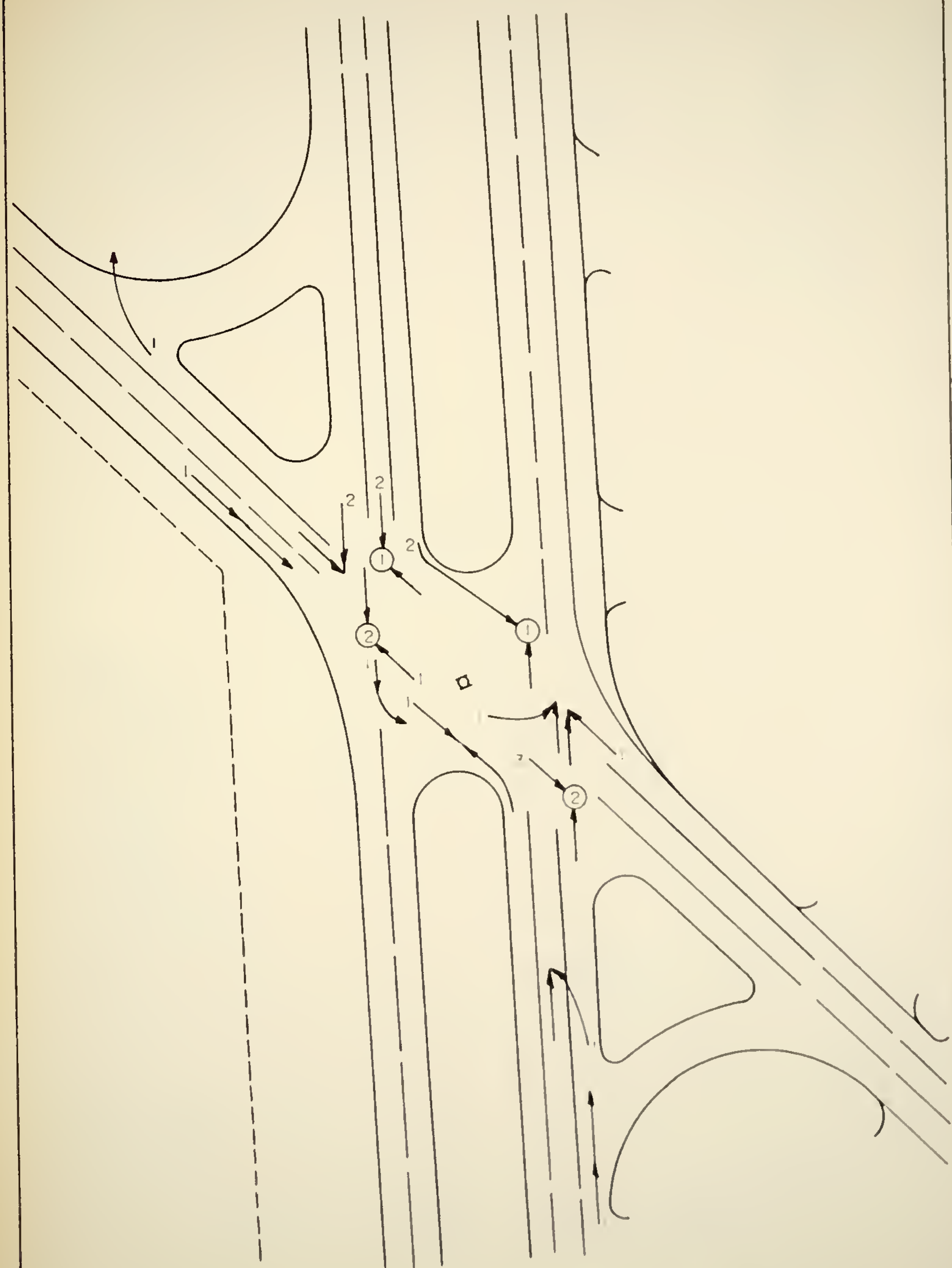


FIG. 92 - U.S. 52 BY-PASS & S.R. 38

1962

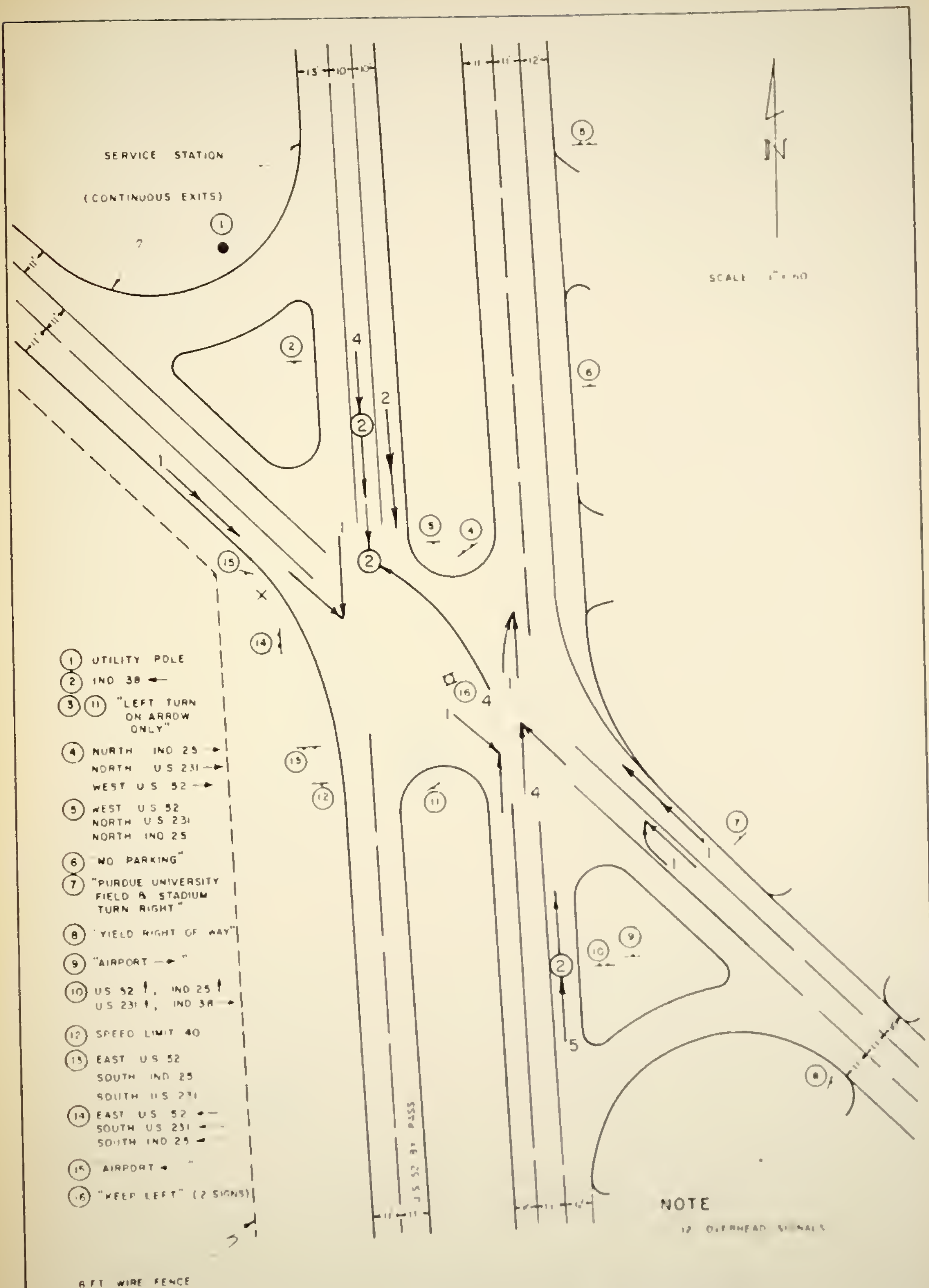
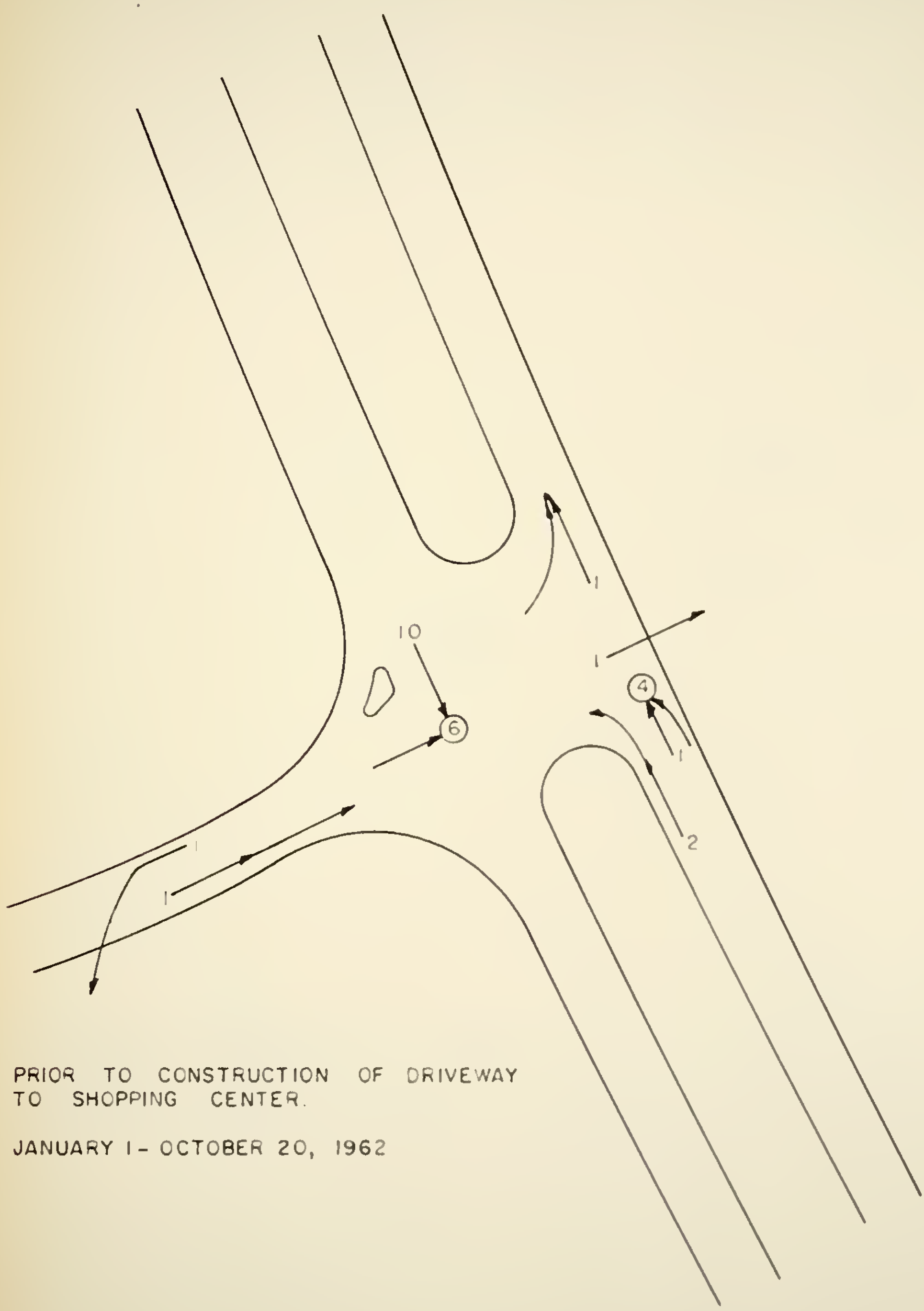


FIG. 93 - U.S. 52 BY-PASS & S.R. 38

1963

FIG. 94 - U.S. 52 BY-PASS & TEAL ROAD

1961



PRIOR TO CONSTRUCTION OF DRIVEWAY TO SHOPPING CENTER.

JANUARY 1 - OCTOBER 20, 1962

FIG. 95 - U.S. 52 BY-PASS & TEAL ROAD

1962 A

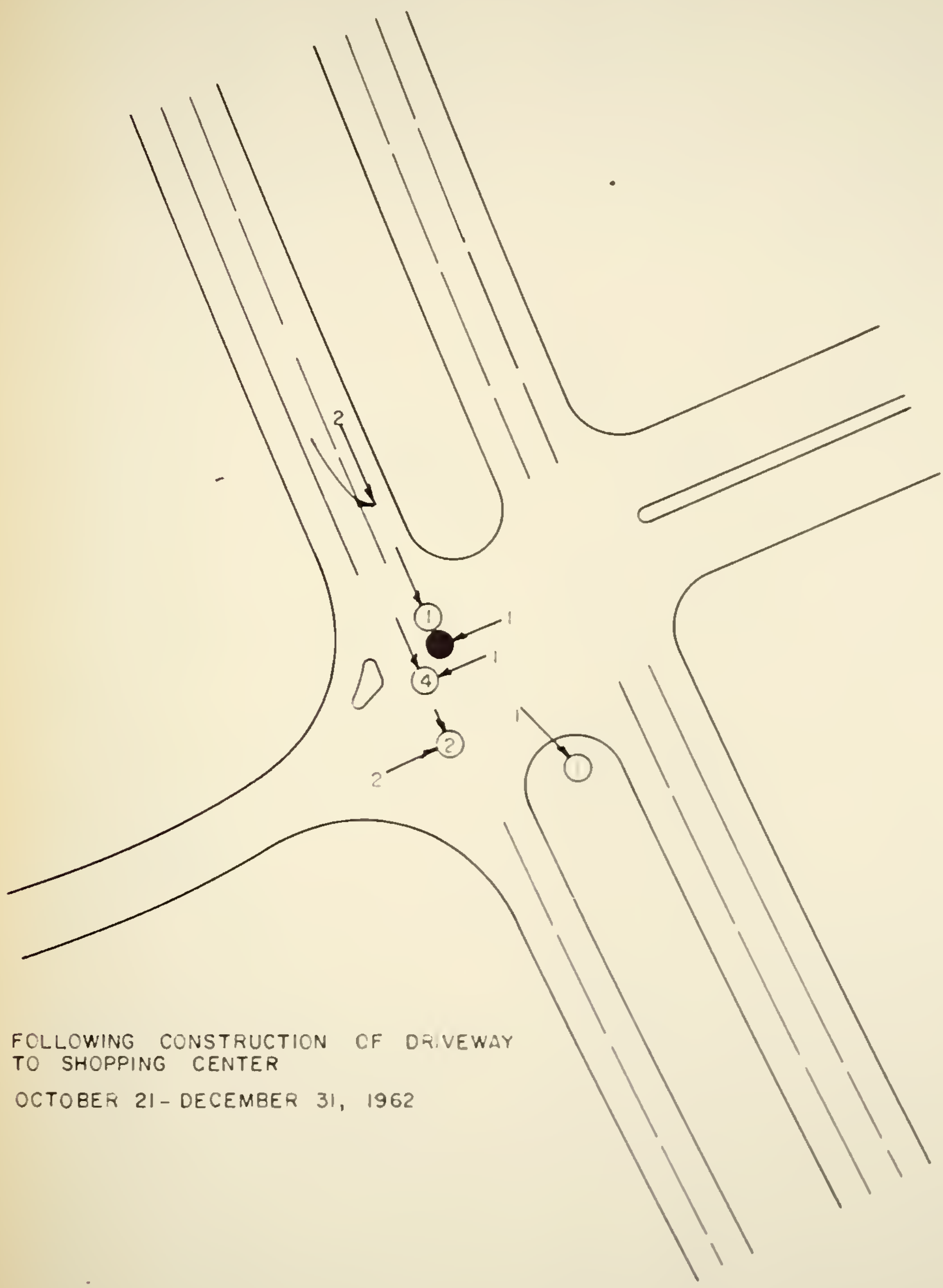


FIG. 96 - U.S. 52 BY-PASS & TEAL ROAD

1962 B

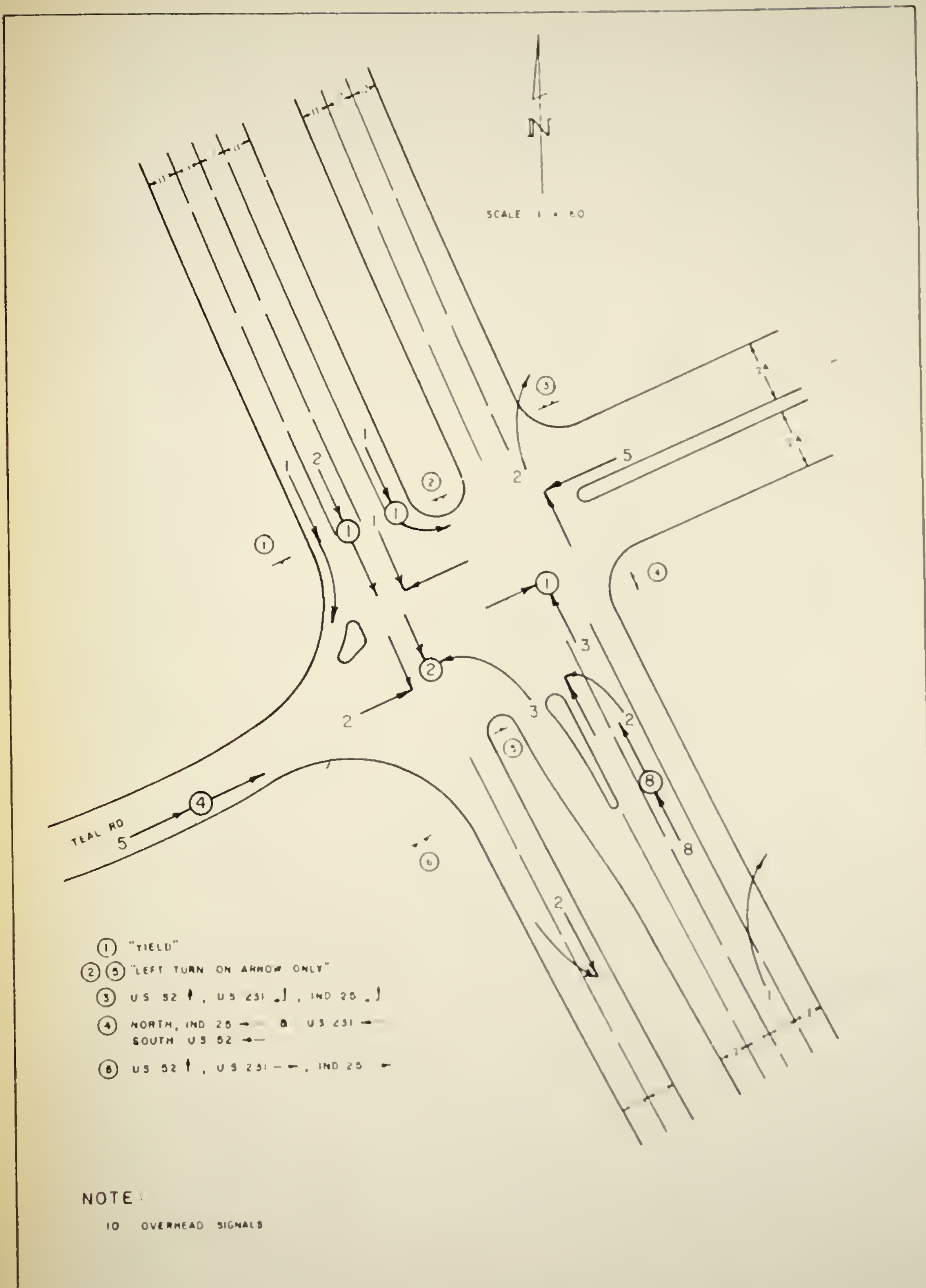


FIG 97 - US 52 BY-PASS & TEAL ROAD

1963